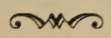
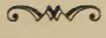
Transactions

of the

American Fisheries Society



EIGHTY-SECOND ANNUAL MEETING
DALLAS, TEXAS
September 8, 9, 10, 1952



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AMERICAN FISHERIES SOCIETY

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THE AMERICAN FISHERIES SOCIETY

Organized 1870 Incorporated 1910

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1 At time of the Annual Meeting, Dallas, Texas.

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PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsquent meeting.

1.	William Clift	1870.1872	New York, N. Y.
2.	William Clift	1872–1873	Albany, N. Y.
3.	William Clift	1873–1874	New York, N. Y.
4.	Robert B. Roosevelt	1874–1875	New York, N. Y.
5.	Robert B. Roosevelt	1875–1876	New York, N. Y.
6.	Robert B. Roosevelt	1876–1877[1]	New York, N. Y.
7.	Robert B. Roosevelt	1877–1878	New York, N. Y.
8.	Robert B. Roosevelt	1878–1879	New York, N. Y.
9.	Robert B. Roosevelt	1879–1880	New York, N. Y.
10.	Robert B. Roosevelt	1880–1881	New York, N. Y.
11.	Robert B. Roosevelt	1881–1882	New York, N. Y.
12.	George Shepard Page	1882–1883	New York, N. Y.
13.	James Benkard	1883–1884	New York, N. Y.
14.	Theodore Lyman	1884–1885	Washington, D. C.
15.	Marshall McDonald	1885–1886	Washington, D. C.
16.	W. M. Hudson	1886–1887	Chicago, Ill.
17.	William L. May	1887–1888	Washington, D. C.
18.	John Bissell	1888–1889	Detroit, Mich.
19.	Eugene G. Blackford	1889–1890	Philadelphia, Pa.
20.	Eugene G. Blackford	1890–1891	Put-in-Bay, Ohio
21.	James A. Henshall	1891–1892	Washington, D. C.
22.	Herschel Whitaker	1892–1893	New York, N. Y.
23.	Henry C. Ford	1893–1894	Chicago, Ill.
24.	William L. May	1894–1895	Philadelphia, Pa.
25.	L. D. Huntington	1895–1896	New York, N. Y.
26.	Herschel Whitaker	1896–1897	New York, N. Y.
27.	William L. May	1897–1898	Detroit, Mich.
28.	George F. Peabody	1898–1899	Omaha, Neb.
29.	John W. Titcomb	1899–1900	Niagara Falls, N. Y.
30.	F. B. Dickerson	1900–1901	Woods Hole, Mass.
31.	E. E. Bryant	1901–1902	Milwaukee, Wis.
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33.	Frank N. Clark	1903–1904	Woods Hole, Mass.
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36.	E. A. Birge	1906–1907	Grand Rapids, Mich.
37.	Hugh M. Smith	1907–1908	Erie, Pa.
38.	Tarleton H. Bean	1908–1909	Washington, D. C.
39.	Seymour Bower	1909–1910	Toledo, Ohio
40.	William E. Meehan	1910–1911	New York, N. Y.
41.	S. F. Fullerton	1911–1912	St. Louis, Mo.

1 A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

42.	Charles H. Townsend	1912–1913	Denver, Colo.
43.	Henry B. Ward	1913–1914	Boston, Mass.
44.	Daniel B. Fearing	1914–1915	Washington, D. C.
45.	Jacob Reighard	1915–1916	San Francisco, Calif.
46.	George W. Field	1916–1917	New Orleans, La.
47.	Henry O'Malley	1917–1918	St. Paul, Minn.
48.	M. L. Alexander	1918–1919	New York, N. Y.
49.	Carlos Avery	1919–1920	Louisville, Ky.
50.	Nathan R. Buller	1920–1921	Ottawa, Ont.
51.	William E. Barber	1921–1922	Allentown, Pa.
52.	Glen C. Leach	1922–1923	Madison, Wis.
53.	George C. Embody	1923–1924	St. Louis, Mo.
54.	Eben W. Cobb	1924–1925	Quebec, P. Q.
55.	Charles O. Hayford	1925–1926	Denver, Colo.
56.	John W. Titcomb	1926–1927	Mobile, Ala.
57.	Emmeline Moore	1927–1928	Hartford, Conn.
58.	C. F. Culler	1928–1929	Seattle, Wash.
59.	David L. Belding	1929–1930	Minneapolis, Minn.
60.	E. Lee LeCompte	1930–1931	Toronto, Ont.
61.	James A. Rodd	1931–1932	Hot Springs, Ark.
62.	H. S. Davis	1932–1933	Baltimore, Md.
63.	Fred A. Westerman	1933–1934	Columbus, Ohio
64.	E. L. Wickliff	1934–1935	Montreal, P. Q.
65.	Frank T. Bell	1935–1936	Tulsa, Okla.
66.	A. G. Huntsman	1936–1937	Grand Rapids, Mich.
67.	I. T. Quinn	1937–1938	Mexico City, Mexico
68.	Fred J. Foster	1938–1939	Asheville, N. C.
69.	T. H. Langlois	1939–1940	San Francisco, Calif.
70.	James Brown	1940–1941	Toronto, Ont.
71.	John Van Oosten	1941–1942	St. Louis, Mo.
72.	John Van Oosten	1942–1943	(No meeting)[2]
73.	John Van Oosten	1943–1944	(No meeting)[3]
74.	John Van Oosten	1944–1945	(No meeting)[3]
75.	John Van Oosten	1945–1946	(No meeting)[3]
76.	Joe Hogan	1946–1947	St. Paul, Minn.
77.	H. H. MacKay	1947–1948	Denver, Colo.
78.	Seth Gordon	1948–1949	Atlantic City, N. J.
79.	Milton C. James	1949–1950	Winnipeg, Man.
80.	Albert S. Hazzard	1950–1951	Memphis, Tenn.
81.	W. J. K. Harkness	1951–1952	Rochester, N. Y.
82.	Ralph Hile	1952–1953	Dallas, Texas

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2 The annual meeting scheduled to be held in New Orleans, La., was cancelled because of the war emergency.

3 No annual meeting scheduled because of the war.

In Memoriam

August J. Anderson, Marquette, Mich.

A. G. Buller, Corry, Pennsylvania

Guy Cary, New York, New York

Capt. C. F. Culler, Minneapolis, Minn.

Edward D. Lapworth, Toronto, Ontario

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Part 1
Papers

FOOD RELATIONSHIPS BETWEEN FLORIDA SPOTTED GAR AND OTHER ORGANISMS IN THE TAMIAMI CANAL, DADE COUNTY, FLORIDA

Burton P. Hunt

Department of Zoology, University of Miami, Coral Gables, Florida

Abstract

An investigation of the food chains leading to the production of Florida spotted gar, *Lepisosteus platyrhincus* DeKay, was conducted in a 3-mile section of the Tamiami Canal approximately 20 miles west of Miami. In this area these fish are extremely abundant, and those collected ranged in length from 10.5 to 24.4 inches. Collections of gar, forage fish, plankton, periphyton, bottom fauna, and physico-chemical data were obtained at frequent intervals from February 20 to June 28, 1952. A total of 448 gar stomachs was examined, of which only 106 (23.7 percent) contained food. Stomachs of 572 specimens of fish, representing 9 species known to serve as food for gar, were obtained and the contents analyzed. Stomachs of fresh-water shrimp, *Palaemonetes paludosa,* and other invertebrates which entered into the food chains were examined.

The diet of the gar consisted principally of fish although 57.5 percent of the stomachs contained shrimp and other invertebrates which comprised 23.6 percent of the total food volume. Four species of fish (bluegill, spotted sunfish, warmouth, and golden topminnow) eaten by gar were carnivorous; their diet was composed of invertebrates alone. Three species (redfin killifish, eastern mosquitofish, and least killifish) were omnivorous and consumed quantities of algae and invertebrates. Two species (sailfin molly and flagfish) were herbivorous, the stomach contents consisting primarily of algae and plant fragments. Algae and fragments of rooted vegetation made up the food of shrimp and most other invertebrates.

The conversion of algae into gar involves only one or two intermediate steps. The two most important food chains are: (1) algae to herbivorous fish and herbivorous invertebrates to gar; (2) algae to herbivorous invertebrates to carnivorous fish and carnivorous invertebrates to gar.

Zoo- and phytoplankton populations in the canal were small. Periphyton, the most common component of which was algae, was extremely abundant, covering all solid objects in the water with a soft slimy coat. The source of algae as the basic food for small fish and invertebrates was periphyton rather than phytoplankton.

Introduction

The Florida spotted gar (*Lepisosteus platyrhincus* DeKay) is extremely abundant in the Tamiami Canal and other drainage canals in southern Florida and appears to be the dominant species of fish in many of these waterways. It is widely distributed throughout the state and is considered to be the Florida representative of the spotted gar, *Lepisosteus productus* (Cope), of the Mississippi drainage system (Hubbs and Allen, 1943).

This study was undertaken to discover the food relationships existing

between the gar and associated organisms, and to determine the nature and source of the basic food organisms which produce and maintain such a large population of carnivorous fish. A 3-mile section of the Tamiami Canal located approximately 20 miles west of Miami was selected for the investigation since it appeared to be typical of canal conditions in this region. Collections of gar, other fish, plankton, periphyton, bottom fauna, and physico-chemical data were obtained at frequent intervals from February 20 to June 28, 1952. Mr. Rhodes B. Holliman, a graduate student at the University of Miami, assisted in the field work.

Methods

Gar were collected by angling, seine, spear, and gill net. The gill net was usually employed, although the spear proved to be very effective and was used exclusively where dense growths of vegetation prohibited the setting of nets. The precipitous canal banks made seining impossible in most places and only moderately effective in a few localities. Small fishes were collected by means of large dip nets and preserved whole. Gar stomachs were removed within 30 minutes after capture and preserved in 10-percent formalin. In the laboratory gar stomachs were opened, flushed clean, the contents identified under a binocular dissecting microscope, and the volume measured by water displacement. The entire intestinal tract was removed from small fishes and the stomach and anterior third of the intestine placed on a ringed slide and opened under a dissecting microscope. The contents were thoroughly scanned under a compound microscope equipped with mechanical stage and objectives giving magnifications of $\times 100$ and $\times 440$.

Qualitative plankton samples were obtained by use of a modified Kemmerer water-sampler and a Wisconsin plankton net made of No. 20 bolting silk. The plankton concentrate was preserved with 5-percent formalin and counted in a Sedgewick-Rafter plankton counting chamber, according to the standard procedure of counting 10 1-cubic-millimeter fields in each of three cells. Plankton tows were taken for qualitative study.

Periphyton collections were obtained by carefully cutting pieces of stem from a variety of submerged plants and preserving them immediately in 5-percent formalin. In the laboratory the periphyton was scraped from the stems, placed in a measured amount of water, teased apart, transferred to a specimen bottle, and gently agitated for one minute. The organisms were counted in a Sedgewick-Rafter plankton counting cell. The bare stem was then measured and the surface area calculated.

Bottom fauna and weed-inhabiting invertebrates were obtained by means of fine-mesh dip nets. Chemical analysis was carried out according to *Standard Methods for the Examination of Water and Sewage* (American Public Health Association, 1936).

Physical, Chemical, and Biological Features

The Tamiami Canal is part of the network of dredged waterways which drain the Everglades south of Lake Okeechobee. It borders the Tamiami

Trail highway and forms a continuous water connection between the Atlantic Ocean at Biscayne Bay and the Gulf of Mexico, by way of connecting canals at Everglades City and Marco. Numerous canals enter it from the north and others extend southward from it. In the study area the direction of the water flow is eastward. When the water level is high a current is perceptible, but during low-water periods the flow is not noticeable. The canal, cut in solid limestone, is approximately 27 to 35 feet wide and varies in depth from about 7 feet during high water to 4 or 5 feet at low water. The bottom consists of a layer of soft mud and debris about 2 feet thick. Adjacent to the culvert at a road crossing, a section of the canal about 300 feet in length has been dredged to a width of 80 feet and a maximum depth of about 12 feet, forming a large pool, herein called the Culvert Pool. The water level fluctuates seasonally, usually being highest in the fall and lowest in late April and May. In the study area it dropped about 24 inches from early March to June.

The water is light brown and Secchi disk readings ranged between 30 and 45 inches. Surface temperature varied between 75° and 91°F., and remained above 80° during May and June. Chemical analyses showed the following variations: free carbon dioxide 3 to 32 p.p.m., dissolved oxygen 1.2 to 7.1, bicarbonates 201 to 270, and total chloride 27 to 34. During the period the pH ranged from 7.2 to 7.7. Carbonates were never present in measurable quantities. The combination of high temperature, abundant free carbon dioxide and bicarbonate provides an excellent environment for the growth of rooted aquatic plants and algae (Prescott, 1951).

Gar and several other species of fish were visibly abundant in the canal, and although a complete inventory was not attempted, the following fishes other than gar were present in considerable numbers: bowfin (*Amia calva*), redfin killifish (*Chriopeops goodei*), flagfish (*Jordanella floridae*), least killifish (*Heterandria formosa*), sailfin molly (*Mollienesia latipinna*), eastern mosquitofish (*Gambusia affinis holbrooki*), warmouth (*Chaenobryttus coronarius*), and spotted sunfish (*Lepomis punctatus*). Other species encountered much less frequently were: golden shiner (*Notemigonus crysoleucas bosci*), brown bullhead (*Ameiurus nebulosus*), tadpole madtom (*Schilbeodes gyrinus*), golden topminnow (*Fundulus chrysotus*), two unindentified species of topminnow (*Fundulus* spp.), largemouth bass (*Micropterus salmoides*), redear sunfish (*Lepomis microlophus*), and bluegill (*Lepomis macrochirus*).

Although no quantitative samples were taken, it appeared that the bottom fauna was relatively poor in species and, with few exceptions, in numbers also. Those organisms which appeared frequently in the qualitative collections were Oligochaeta, the very abundant and ever-present fresh-water shrimp (*Palaemonetes paludosa*), damselfly (Zygoptera) nymphs, numerous dipterous larvae, chiefly Chironomidae, both adults and larvae of the beetle family Haliplidae, water mites (Hydracarina), and snails belonging to the families Physidae, Planorbidae and Ancylidae. Organisms encountered less frequently were large ostracods, scuds (*Hyalella*), crayfish, mayfly (Ephemeroptera) and dragonfly (Anisoptera)

nymphs, Hemiptera (*Corixa, Ranatra,* and *Benacus*), carnivorous beetles of the family Hydrophilidae, and caddisfly (Trichoptera) larvae.

The net plankton, never visibly abundant, was composed principally of bluegreen algae (Myxophyceae), green algae (Chlorophyceae), diatoms (Bacillariophyceae), rotifers, copepods, and cladocerans. Counts of the phytoplankters in seven quantitative samples taken between February and June gave the following number of units per liter: bluegreens, 180 to 620, average 337; greens, 500 to 5,050, average 1,575; diatoms 480 to 3,550, average 1,442. On a numerical basis, the bluegreens comprised 10 percent of the plankton algae, the greens 47 percent, and diatoms 43 percent. Other groups of algae were poorly represented. Rotifera were present in all samples and varied in abundance from 50 to 550 per liter. Copepods and cladocerans were present in most samples but were not numerous enough to count by the methods used. *Cyclops, Pleuroxus, Chydorus,* and nauplii occurred in small numbers. *Diaptomus, Daphnia,* and *Bosmina* were rare. Protozoans, such as *Vorticella, Dinobryon,* and unindentified ciliates, occurred infrequently. The relatively small amount of net plankton did not appear to offer an adequate food supply for those fishes which feed upon such organisms.

The periphyton, that heterogenous assemblage of algae and minute animals which covers all solid submerged objects with a slimy coating, was moderately abundant in February and rapidly increased in amount until in June it formed a conspicuous, fuzzy layer on the stems and leaves of all aquatic plants. The number of units of algae per square centimeter of plant-stem surface increased from an average of 50,000 in March to 392,700 in June, an eight-fold increase. The algae included many filamentous species as well as all forms found in the plankton. The numerical composition of the algae was: bluegreens, 3 to 6 percent; greens, 12 to 20 percent; diatoms, 74 to 85 percent. The number of diatoms, including many very small forms, ranged from 37,300 to 324,800 per square centimeter of surface. In the Tamiami Canal the usual number of diatoms per square decimeter of plant-stem surface ranged between 4 and 33 million as compared to the usual range of 3 to 9 million in Douglas Lake, Michigan (Young, 1945). Total units of green algae, including the desmids, ranged from 1 to 4.7 million per square decimeter as compared to a range of 44,000 to 2.8 million (desmids only) in Douglas Lake. Rotifers, sufficiently abundant to count by the methods used, averaged 450 per square centimeter of surface. The number of algae per square centimeter of periphyton was 15 to 117 times greater than the average number of net phytoplankters per liter. Animals present in the periphyton were oligochaetes, chironomid larvae, copepods, cladocerans, ostracods, water mites, and snails. All species of algae and most animals found in the intestinal tracts of fishes and invertebrates examined were also present in the periphyton, which provided an abundant food supply for these animals.

Submerged vegetation, consisting principally of *Myriophyllum, Ceratophyllum, Potamogeton,* and *Najas,* was abundant throughout the period

of investigation. In late spring the increased growth rate of these plants, together with receding water levels, caused the vegetation to reach the surface of the water and fill much of the canal to such an extent that it was impossible to use gill nets or seines effectively. The luxuriant growth of vegetation did not appear to cause the gar and other fish to move to other areas. One small section of the study area about 400 yards long was thickly covered with water hyacinth (*Eichòrnia crássipes*) at the beginning of the study. These plants were sprayed and destroyed in April.

Spotted Gar Population

The great number of gar in the Tamiami and other canals in the area can scarcely be appreciated unless actually seen. Facilities were not available for a much needed and much desired population study and count of the number per acre of water; however, a suggestion of their abundance may be obtained from the following observations. As many as 270 have been counted in 100 yards of canal. Before the canal was choked with vegetation, one set of a gill net across the channel was sufficient to take from 12 to 25 gar in a period of 10 to 20 minutes. The capture of these fish was so rapid that the net was continually patroled by rubber boat and the gar removed as they became entangled. The number of gar usually concentrated in the Culvert Pool was estimated at more than 2,000. On April 9, 110 feet of gill net, placed in the pool for not more than 10 minutes, captured 245 of these fish. Two weeks later one partially successful haul of a seine 50 feet long and 5 feet high resulted in the capture of 285 individuals by actual count. Mr. James A. DeJean, Fish Management Technician, Florida Game and Fresh Water Fish Commission, states (unpublished report) that in a recent fish-poisoning operation in a canal in Broward County, 2,199 gar weighing 879.6 pounds were removed from one section 50 feet wide and 300 feet long, and that from another section of similar size 686 gar were collected weighing 275.9 pounds. The large number of these obnoxious fish greatly interferes with anglers in their attempt to catch black bass and pan fish.

The 611 gar captured in this study ranged in length from 10.5 to 24.4 inches. Few individuals exceeded 20 inches in length. A series of 108 representative specimens captured on March 12, 26, and April 9 averaged 15.8 inches in length and 11.4 ounces in weight. The length-weight relationship is shown in Figue 1.

Feeding Habits and Food of the Spotted Gar

Stomachs were removed from 448 of the 611 gar killed during the course of the study. Of these, 342 (76 percent) were empty and 106 (24 percent) contained food. There is no obvious explanation of the exceedingly large number of empty stomachs. Regurgitation was never observed although dozens of individuals were watched as they entered the gill net within 5 feet of the operator and were removed immediately. Furthermore, no differ-

ence was evident in the stomach content of those captured by gill net and by spear during the same collecting periods. Other food studies of gars have also shown a large number of empty stomachs. Coker (1930) reported that 66 percent of the shortnose gar stomachs examined were empty. Lagler, Obrecht, and Harry (1953) observed that 80 percent, 46 percent, and 45 percent of the stomachs of longnose, shortnose, and spotted gar, respectively, were empty. In a study of the food habits of *Lepisosteus*, Scott (1938) found that 50 of 89 specimens contained no food.

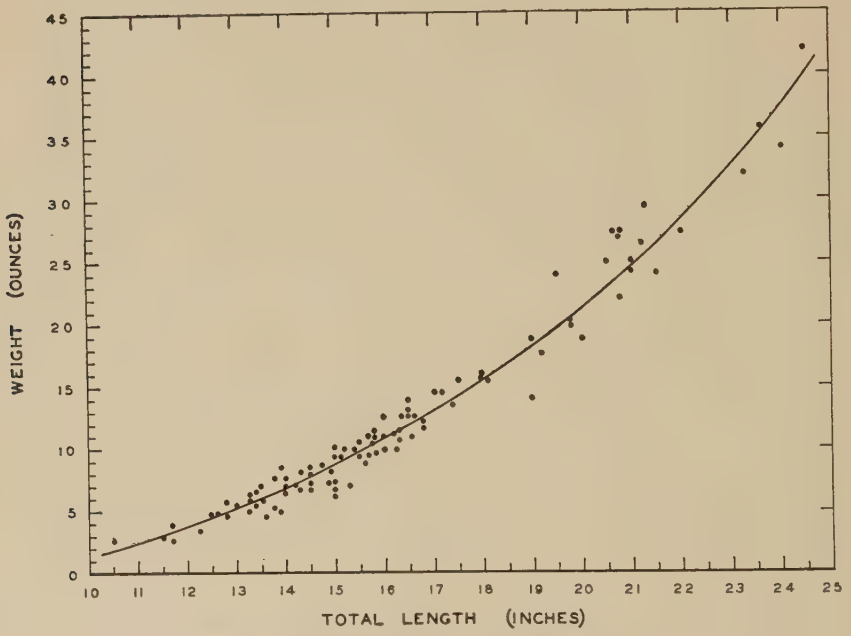

FIGURE 1.—Length-weight relationship of the Florida spotted gar in the Tamiami Canal.

Collections for the present study were usually made in mid-morning or mid-afternoon; however, some were obtained at hourly intervals over a 3-hour period beginning at daylight on some occasions and extending from mid-afternoon until dark on others. Despite the fact that gar were collected and observed at various hours of the day from daylight until dark, no periodicity of feeding was evident. On only one occasion were gar observed feeding avidly. The entire population appeared to be actively foraging between 1:30 and 3:00 p.m. on March 5, and all stomachs obtained at that time were packed with recently eaten fish. The data indicate that heavy feeding was more prevalent in February and March than later in the spring, when the total food intake was low and consisted of a markedly greater percentage of invertebrates.

All species of *Lepisosteus* are known to be highly piscivorous (Bonham, 1941; Lagler and Hubbs, 1940; Lagler, Obrecht, and Harry, 1943; Scott, 1938, and others). For this reason they are considered as highly undesirable predatory fish. Unquestionably the populations of largemouth bass and pan fish in the Tamiami Canal are adversely affected by the predation and competition of the gar.

Of the stomachs examined in the present study, 70 percent contained fish, which constituted 76.4 percent of the total volume of food present (Table 1). No other vertebrates had been consumed. Most fish were digested beyond recognition. Of those identified, eastern mosquitofish occurred more frequently than any other fish, followed by redfin killifish, flagfish, Centrarchidae, least killifish, and sailfin molly. The Centrarchidae were principally young warmouth and spotted sunfish, although the bluegill was represented. Those gar which had eaten fish contained an average of approximately three individuals per stomach. *Fundulus* was not identified in the stomachs but is almost certainly preyed upon by gar. In this locality the fishes eaten were predominantly members of the families Cyprinodontidae and Poeciliidae, whereas consumption of other fishes was low. That gar often consume an appreciable number of game and pan fishes is evident from published reports (Bonham, 1941; Coker, 1930; Lagler, Obrecht, and Harry, 1943; Parker, 1939, and others).

Invertebrates, found in 57.5 percent of the stomachs containing food, comprised 23.7 percent of the total food volume (Table 2). Although a variety of invertebrates was consumed, only the fresh-water shrimp *Palaemonetes paludosa* was of consequence. This species, eaten by 38.7 percent of the gar, comprised 16.5 percent of the total food volume. This shrimp is reported to be of considerable importance in the diet of spotted gar in Texas (Bonham, 1941). Crayfish, scuds, and ostracods were consumed infrequently. Among the insects, dragonfly and damselfly nymphs were eaten most frequently and formed an appreciable volume of food. Mayfly nymphs (*Caenis* and *Callibaetis*) and adult Hemiptera (*Benacus* and *Ranatra*) were eaten occasionally, while water boatmen (*Corixa*) appeared more often. Beetles were represented by the families Haliplidae and Hydrophilidae. Diptera in the diet consisted of larvae of Chironomidae and *Chaoborus*. Other invertebrates consumed were one ant and two snails.

Food of Fishes Eaten by Spotted Gar

The species of fish eaten by gar show greatly diversified feeding habits and food requirements and range from typical herbivores to typical carnivores. The amounts of plant and animal food consumed by these forage fishes shows the relative position of each in the food chains leading to the production of spotted gar (Table 3.)

Plant food consisted primarily of recognizable algae and small amounts of vegetable debris, mostly of algal origin. The nutritional value of various forms of algae are unknown, but it is only logical to believe that the larger filamentous and many-celled colonial forms constituted the most important

TABLE 1.—*Percentage frequency of occurrence and percentage of total food volume of fish in the gar diet*

Date of collection	Stomachs examined		Redfin killifish		Flagfish		Least killifish		Sailfin molly		Eastern mosquitofish		Centrarchidae		Fish remains		All fish	
	Total number	Number containing food	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume
Feb. 20	7	7	.....	.....	.....	.....	.....	.....	.....	.....	28.6	32.2	.....	.....	42.8	48.2	71.4	80.4
do. 27	7	4	.....	.....	.....	.....	25.0	12.9	.....	.....	25.0	22.6	.....	.....	75.0	61.3	75.0	96.8
Mar. 5	16	16	37.5	10.2	31.2	43.1	25.0	2.3	.....	.....	68.7	16.0	6.2	11.7	43.7	12.4	93.7	95.7
do. 12	23	6	.....	.....	.....	.....	.....	.....	.....	.....	16.7	12.5	16.7	5.0	66.7	72.5	83.3	90.0
do. 26	18	12	.....	.....	8.3	27.9	.....	.....	8.3	11.5	25.0	13.6	.....	.....	91.7	46.4	100.0	99.4
April 9	82	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	100.0	100.0	.....	.....	100.0	100.0
do. 23	57	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	50.0	50.0	50.0	50.0
May 7	42	30	6.7	1.3	6.7	2.3	.....	.....	.....	.....	10.0	1.3	16.7	30.8	56.7	16.2	56.7	51.9
do. 14	6	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	50.0	6.3	50.0	6.3
do. 21	23	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	33.3	76.4	33.3	4.5	66.7	80.9
June 10	36	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	100.0	100.0	100.0	100.0
do. 20	85	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
do. 28	46	21	9.5	7.0	4.8	2.0	.....	.....	.....	.....	9.5	10.4	.....	.....	28.6	12.9	38.1	32.3
Total or average	448	106	9.4	4.8	8.5	20.7	4.7	1.0	0.9	1.7	21.7	10.5	5.7	17.0	51.9	20.7	70.0	76.3

TABLE 2.—*Percentage frequency of occurrence and percentage of total food volume of invertebrates in the gar diet*
[Tr. = trace]

Date of collection	Stomachs examined		Palaemonetes		Other Crustacea		Ephemeroptera and Odonata		Hemiptera, Coleoptera, and Diptera		All invertebrates	
	Total number	Number containing food	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume
Feb. 20	7	7	28.6	12.5	14.3	Tr.	14.3	Tr.	28.6	7.1	57.1	19.6
do. 27	7	4	....	....	....	....	25.0	3.2	....	....	25.0	3.2
Mar. 5	16	16	6.2	1.1	....	....	6.2	1.8	6.2	1.4	18.7	4.3
do. 12	23	6	....	....	16.7	10.0	....	....	....	....	16.7	10.0
do. 26	18	12	16.7	0.6	....	....	....	....	....	....	16.7	0.6
April 9	82	1	....	....	....	....	....	....	....	....	....	....
do. 23	57	2	50.0	50.0	....	....	50.0	Tr.	....	....	100.0	50.0
May 7	42	30	86.7	46.1	....	....	6.7	1.7	6.7	0.3	90.0	48.1
do. 14	6	2	50.0	6.3	....	....	50.0	87.4	....	....	50.0	93.7
do. 21	23	3	100.0	10.1	....	....	....	....	33.3	9.0	100.0	19.1
June 10	36	1	....	....	....	....	....	....	100.0	Tr.	100.0	Tr.
do. 20	85	1	....	....	....	....	100.0	100.0	....	....	100.0	100.0
do. 28	46	21	23.8	22.4	9.5	34.8	23.8	4.0	43.1	6.5	81.0	67.7
Total or average	448	106	38.7	16.5	3.8	3.3	12.3	2.2	15.1	1.6	57.5	23.7

food items. Green algae (Chlorophyceae) were eaten extensively and formed the greatest volume of plant food. Genera of common occurrence in the intestinal tracts of all fish which consumed quantities of algae were: *Eudorina, Ulothrix, Hormidium, Microspora, Oedogonium, Bulbochaeta, Pediastrum, Ankistrodesmus, Scenedesmus, Mougeotia, Zygnema, Spirogyra,* and the desmid genera *Closterium, Euastrum, Cosmarium, Micrasterias, Staurastrum,* and *Desmidium. Diatoms* (Bacillariophyceae), very abundant in many fish stomachs, probably contributed only a small part to the total food volume. Those frequently encountered were: *Stephanodiscus, Tabellaria, Fragilaria, Synedra, Navicula, Cymbella,* and *Amphora.* Bluegreen algae (Myxophyceae) were eaten much less extensively and usually comprised a minor part of the total food volume. Genera frequently found were: *Chroöcoccus, Merismopedia, Oscillatoria,* and *Lyngbya.*

Animal food was found in the intestinal tracts of all small fishes but comprised a major part of the diet of only a few species. Protoza, found infrequently in the stomach contents, were represented by *Vorticella, Dinobryon,* and unidentified ciliates. Rotifers (*Polyarthra, Keratella, Asplanchna,* and *Brachionus*) appeared in many intestinal tracts but probably contributed little to the total food volume. Entomostraca commonly represented in the food were *Cyclops, Pleuroxus, Chydorus,* and various ostracods, but *Diaptomus, Daphnia* and *Bosmina* were rarely eaten. Scuds and fresh-water shrimp appeared in the stomachs of only a few species of fish. Damselfly and mayfly nymphs were present in moderate numbers. Dipterous larvae, principally chironomids, occurred in the diet of most fishes and formed a considerable part of the food volume. Caddisfly larvae, Hemiptera, beetles, water mites and snails were eaten occasionally by certain species of fishes.

The food and feeding habits of the various species of fish which were eaten by gar are discussed in the following pages.

Sailfin molly (Mollienesia latipinna).—Stomachs and intestines of the 52 specimens examined were all well filled with an accumulation of algae and plant debris, which formed essentially 100 percent of the food volume. Green algae and diatoms were abundant in every specimen examined, but bluegreen algae were encountered less frequently. Animal food, found in only 15.4 percent of the fish, consisted principally of rotifers and a few small ostracods. Composition of the intestinal content was closely similar to that of the periphyton, which apparently is the primary source of food. On occasion, individuals have been seen removing the periphyton from stems of aquatic plants by a scraping method of feeding. Hiatt (1947) reported that this fish feeds entirely on the periphyton and plant debris in Hawaiian fish ponds and competes directly with economically important fish with similar food habits. This herbivore is of great importance as a link in food chains since it converts plants directly into fish flesh available for predatory animals.

Flagfish (Jordanella floridae).—Plants constituted the principal component of the contents of 77 intestinal tracts examined, and comprised an estimated 95 percent of the total volume of food (Table 4). All tracts were

TABLE 3.—*Occurrence of algae and animal food in the diet of fishes preyed upon by gar*
[A=abundant; S=sparse; R=rare]

Fish	Number of specimens	Range in total length (millimeters)	Algae			Animals		
			Percentage frequency of occurrence	Relative abundance	Percentage of total food volume	Percentage frequency of occurrence	Average number per stomach	Percentage of total food volume
Sailfin molly	52	28–63	100.0	A	100.0	15.4	0.2	Trace
Flagfish	77	24–47	100.0	A	95.0	44.1	5.3	5.0
Least killifish	125	12–25	100.0	A	80.0	63.2	2.7	20.0
Eastern mosquitofish	174	13–47	93.1	A	60.0	62.1	2.4	40.0
Redfin killifish	93	22–39	41.9	S	5.0	100.0	10.7	95.0
Golden top minnow	17	41–68	5.9	R	Trace	100.0	5.8	100.0
Lepomis spp.	22	22–46	.....	...	.....	100.0	14.5	100.0
Warmouth	12	35–90	.....	...	.....	100.0	4.2	100.0

TABLE 4.—*The percentage frequency of occurrence of major groups of food organisms eaten by the flagfish* (Jordanella floridae)

Item	Date								Total or average
	Mar. 5	Mar. 12	Mar. 26	April 9	April 23	May 7	May 21	June 10	
Number of specimens	20	6	3	14	10	15	6	3	77
Food organisms									
Algae	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Myxophyceae	45.0	100.0	100.0	100.0	100.0	.....	.....	.....	54.5
Chlorophyceae	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Bacillariophyceae	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Animals	.....	83.3	66.7	78.6	40.0	66.7	.....	66.7	44.1
Rotifera	.....	83.3	33.3	78.6	10.0	13.3	.....	66.7	28.6
Copepoda	.....	16.7	33.3	50.0	10.0	26.7	.....	.....	18.2
Cladocera	.....	66.6	33.3	50.0	20.0	20.0	.....	66.7	24.7
Ostracoda	.....	33.3	.....	7.1	.....	53.3	.....	66.7	16.9
Ephemeroptera	.....	.....	.....	.....	.....	6.7	.....	.....	1.3
Diptera	.....	16.7	.....	50.0	20.0	.....	.....	.....	13.0

well filled with a variety of green algae, diatoms, and bluegreen algae. A considerable quantity of fresh fragments of *Myriophyllum* had also been consumed.

Animals occurred in the digestive tract of 44.1 percent of the fish and comprised about 5 percent of the total food volume. Rotifers and small cladocerans appeared most frequently, followed by copepods and ostracods. Other invertebrates occurred infrequently. The general appearance of the food material eaten resembled closely the composition of the periphyton. On several occasions this fish was seen eating small fragments of periphyton dislodged from submerged vegetation by the writer. This species is also an important link in the direct conversion of algae and plant material into fish tissue.

Least killifish (Heterandria formosa).—The least killifish is very abundant in the canals of southern Florida and is probably eaten more extensively by gar than is indicated in Table 1. All fish examined had consumed a large number of species of algae as well as a considerable variety of animals. The contents of 125 alimentary tracts examined showed that although this fish is truly omnivorous in its feeding habits, its diet is predominantly algae and plant debris (Table 5). Algae, mostly greens and diatoms, were always present in large quantities in every stomach and comprised about 80 percent of the total food volume. Although diatoms were abundant, the volume was small except on a few occasions such as April 23, when stomachs were filled with a large species of *Synedra*. Bluegreen algae were eaten in small amounts except on February 20 and April 9, when exceptionally large quantities of *Oscillatoria* occurred in many stomachs.

Animal food, forming an estimated 20 percent of the total food volume, was composed mainly of rotifers, copepods, cladocerans and Diptera (chiefly Chironomidae). Scuds, mayfly nymphs, beetles, water mites, and snails were eaten sparingly.

These little fish always congregated wherever masses of periphyton were dislodged from submerged plants and actively fed on the floating material. The author has kept several individuals in a small aquarium supplied occasionally with fresh pieces of aquatic plants covered with periphyton and they have thrived on this food supply. Mellen (1927) stated that *H. formosa* is "omnivorous with a decided preference for animal food." Seal (1910) implied that it is a surface feeder and shows a preference for insect food. This study indicates that although omnivorous, it is predominantly herbivorous in the Tamiami Canal and is an important agent in converting plant material into animal protoplasm in suitable form for piscivorous fishes.

Eastern mosquitofish (Gambusia affinis holbrooki).—The eastern mosquitofish has long been considered an important and successful agent in the control of mosquito populations by eating the larvae and pupae (Hildebrand, 1919, 1921; Kuntz, 1914; Seal, 1910; Self, 1940; and others). Comparatively little attention has been given to the role of this fish in the food-chain relationships between basic food materials and piscivorous

TABLE 5.—*The percentage frequency of occurrence of major groups of food organisms eaten by the least killifish* (Heterandria formosa)

Item	Date											Total or average
	Feb. 20	Feb. 27	Mar. 5	Mar. 12	Mar. 26	April 9	April 23	May 7	May 21	June 10	June 20	
Number of specimens	15	5	19	10	15	7	10	14	10	10	10	125
Food organisms												
Algae	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Myxophyceae	100.0	80.0	89.5	100.0	46.7	100.0	40.0	.....	50.0	20.0	30.0	59.2
Chlorophyceae	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Bacillariophyceae	86.7	100.0	100.0	90.0	71.4	100.0	80.0	100.0	100.0	100.0	100.0	92.8
Animals	80.0	80.0	5.3	70.0	80.0	71.4	60.0	57.1	90.0	80.0	70.0	63.2
Rotifera	60.0	20.0	10.5	20.0	20.0	57.1	40.0	.....	70.0	50.0	40.0	32.8
Copepoda	20.0	60.0	.....	20.0	46.7	57.1	50.0	50.0	10.0	10.0	20.0	28.0
Cladocera	.....	20.0	.....	40.0	60.0	.....	20.0	35.7	.....	10.0	.....	17.6
Ostracoda	6.7	.....	.....	10.0	.....	.....	.....	.....	.....	40.0	10.0	5.6
Hydracarina	.....	.....	.....	10.0	.....	14.3	.....	.....	10.0	.....	10.0	3.2
Ephemeroptera	.....	.....	.....	.....	.....	.....	10.0	7.1	10.0	.....	20.0	4.0
Diptera	33.3	60.0	5.3	20.0	6.7	42.8	20.0	7.1	10.0	30.0	40.0	20.8
Other insects	6.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.8
Mollusca	.....	.....	.....	10.0	.....	.....	10.0	.....	.....	.....	.....	1.6
Other animals	.....	.....	.....	.....	6.7	.....	.....	.....	.....	.....	.....	0.8

fishes. Bonham (1941) reported that *Gambusia* was frequently eaten by spotted and longnose gars in Texas, and the present study reveals its importance as a forage fish in areas where it is abundant.

Although *Gambusia* is usually considered a surface feeder with a predilection for insects and insect larvae, Hildebrand (1921) reported that the majority of stomachs examined "contained plant tissue consisting mostly of algae." Examination of the stomachs of 105 *Gambusia affinis* from Louisiana (Barney and Anson, 1920) led to the conclusion that it was a plankton feeder since the volume of stomach contents consisted of the following items: algae, 47.7 percent; unrecognizable debris, 14.4 percent; Entomostraca, Rotifera, and Protozoa, 30 percent; and insects only 6.1 percent. Ward (1931) examined the stomach contents of 70 specimens of *"Gambusia holbrooki"* from Florida and reported algae present in most stomachs along with entomostracans and chironomid larvae. Studies of the food of *Gambusia affinis* in Hawaiian fish ponds (Hiatt, 1947) showed the diet to consist principally of algae (green algae and diatoms), plant fragments, and debris, and rarely animal food such as Entomostraca and insects.

The frequency of occurrence of various food items in the 174 fish examined is shown in Table 6. The same organisms were eaten by both small and large *Gambusia* and no seasonal variation in the diet was apparent. The stomach contents consisted principally of algae, which formed an estimated 60 percent of the food volume. The algae in the digestive tracts were similar to those in the periphyton rather than to those in the phytoplankton, although many of the components of the latter were also present in the food. Of the animal food, estimated to form 40 percent of the volume of stomach contents, chironomid larvae were taken most consistently and formed the greatest bulk. Entomostraca appeared frequently and were consumed in considerable numbers. Miscellaneous animals included ants, water boatmen, small beetles, Thysanoptera, scuds, spiders, oligochaetes, and ciliated protozoans. Mosquito larvae occurred in only two stomachs. Only 7 percent of the specimens contained animal food exclusively. An unusual find was a 10-millimeter centrarchid in the stomach of a mosquitofish 33 millimeters long. *Gambusia a. holbrooki* is truly omnivorous and apparently opportunistic in its feeding on both plants and animals. The flexibility of its food habits accounts in part for the abundance of this fish within its natural range. Although it may prefer an insect diet when available, it can subsist largely on algae and thus is important in converting plants directly into animal tissue.

Redfin killifish (Chriopeops goodei).—This species, very numerous in the study area, inhabits the deeper water and vegetation. Examination of the food eaten shows this killifish to be decidedly carnivorous (Table 7). Despite the fact that nearly half of the stomachs (41.9 percent) contained various forms of algae, this food was rare, and although a regular constituent of the diet, was relatively unimportant in relation to the total food consumed, comprising about 5 percent.

Animals had been eaten by all specimens and constituted about 95 percent of the total volume of food. Chironomid larvae were the most

TABLE 6.—*The percentage frequency of occurrence of major groups of food organisms eaten by the eastern mosquitofish* (Gambusia affinis holbrooki)

Item	Date											Total or average
	Feb. 20	Feb. 27	Mar. 5	Mar. 12	Mar. 26	April 9	April 23	May 7	May 21	June 10	June 20	
Number of specimens	20	23	15	16	15	15	15	20	15	10	10	174
Food organisms												
Algae	95.0	87.0	100.0	100.0	100.0	100.0	100.0	80.0	100.0	100.0	60.0	93.1
Myxophyceae	95.0	21.7	53.3	50.0	46.7	100.0	40.0	.....	20.0	.....	.....	40.8
Chlorophyceae	75.0	87.0	100.0	100.0	100.0	100.0	100.0	80.0	100.0	100.0	60.0	90.8
Bacillariophyceae	85.0	78.3	86.7	50.0	86.7	100.0	100.0	55.0	93.3	30.0	60.0	76.4
Animals	75.0	69.6	20.0	56.2	73.3	53.3	40.0	65.0	73.3	90.0	70.0	62.1
Rotifera	40.0	17.4	.....	25.0	13.3	.....	13.3	5.0	53.3	10.0	.....	17.2
Copepoda	5.0	8.7	.....	6.2	13.3	6.7	.....	25.0	.....	.....	10.0	7.5
Cladocera	5.0	26.1	6.7	12.5	33.3	6.7	.....	15.0	.....	.....	30.0	12.6
Ostracoda	10.0	.....	.....	6.2	.....	6.7	6.7	15.0	13.3	20.0	30.0	8.6
Hydracarina	.....	.....	.....	.....	20.0	20.0	.....	.....	.....	10.0	.....	4.0
Ephemeroptera	10.0	.....	.....	12.5	40.0	13.3	6.7	15.0	26.7	.....	.....	11.5
Odonata	.....	.....	.....	.....	.....	.....	.....	5.0	.....	.....	.....	0.6
Diptera	20.0	39.1	6.7	31.2	20.0	.....	6.7	10.0	.....	10.0	40.0	17.2
Other insects	15.0	4.3	6.7	.....	13.3	6.7	6.7	10.0	.....	40.0	30.0	10.3
Mollusca	.....	.....	.....	.....	.....	.....	6.7	5.0	.....	10.0	20.0	2.9
Other animals	.....	.....	.....	.....	6.7	13.3	.....	10.0	.....	30.0	10.0	5.2

TABLE 7.—*The percentage frequency of occurrence of major groups of food organisms eaten by the redfin killifish* (Chriopeops goodei)

Item	Date								Total or average
	Feb. 27	Mar. 26	April 9	April 23	May 7	May 21	June 10	June 20	
Number of specimens	1	10	15	20	14	15	10	8	93
Food organisms									
Algae	.....	10.0	93.3	65.0	14.3	40.0	10.0	12.5	41.9
Myxophyceae	.....	.....	33.3	.....	.....	.....	.....	.....	5.4
Chlorophyceae	.....	20.0	93.3	65.0	14.3	40.0	10.0	12.5	41.9
Bacillariophyceae	.....	.....	46.7	35.0	.....	.....	.....	.....	15.1
Animals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Rotifera	.....	30.0	.....	45.0	.....	33.3	20.0	25.0	22.6
Copepoda	100.0	80.0	86.7	65.0	14.3	46.7	40.0	37.5	54.8
Cladocera	100.0	70.0	66.7	35.0	21.4	60.0	30.0	87.5	50.5
Ostracoda	100.0	20.0	46.7	55.0	42.8	73.3	90.0	87.5	58.1
Hydracarina	.....	.....	40.0	5.0	7.1	.....	.....	.....	8.6
Ephemeroptera	100.0	40.0	53.3	15.0	42.8	20.0	.....	.....	26.9
Odonata	.....	.....	6.7	.....	.....	.....	.....	12.5	2.2
Diptera	.....	50.0	80.0	85.0	42.8	66.7	90.0	62.5	68.8
Other insects	.....	.....	.....	5.0	.....	6.7	.....	.....	2.2
Mollusca	.....	.....	13.3	10.0	7.1	13.3	.....	25.0	9.7
Other animals	.....	.....	.....	.....	28.7	.....	10.0	.....	5.4

important items in the diet and formed the greatest bulk of animal food. Ostracods, copepods, cladocerans, and mayfly nymphs were consumed in large numbers, while caddis larvae, scuds, snails, water mites, and rotifers occurred less frequently. Since most of the animals consumed belong to the benthos, this fish is classed as a bottom feeder. The ecological position of this species is that of an intermediate link between small herbivorous invertebrates and piscivorous fishes.

Golden topminnow (Fundulus chrysotus).—This fish was not common in the study area; only 17 were captured during the investigation. All stomachs contained invertebrates but only one contained algae, which indicates that this topminnow does not consume plants to an appreciable extent. Small beetles of the family Haliplidae were present in 76.5 percent of the stomachs and constituted the bulk of the food. Chironomid larvae occurred in 23.5 percent of the stomachs. Mayfly and damselfly nymphs, beetle larvae, snails, water boatmen, adult midges, and Collembola were consumed in small numbers. This fish appears to be wholly carnivorous and seemingly takes larger invertebrates than do the other cyprinodontids and poeciliids. The golden topminnow also is an intermediate link between the invertebrates and the larger carnivores. The stomachs of three other specimens representing two unidentified species of *Fundulus* contained animal food similar to that of *F. chrysotus*. Pearse (1918, 1922) reported that the food of *Fundulus diaphanus menona* was composed chiefly of Entomostraca, insects, scuds, water mites, mollusks, oligochaetes and other aquatic invertebrates; algae composed only 6.4 percent of the food.

Centrarchidae.—Twelve of 25 small warmouth collected contained food material composed exclusively of animals. Food organisms identified were: dragonfly, damselfly, and mayfly nymphs; dipterous larvae of various kinds; a few scuds and large ostracods; and a large number of small shrimp, *Palaemonetes paludosa*. Two bluegills and 20 spotted sunfish had eaten animal food exclusively. Copepods were consumed most frequently (77.3 percent), followed by ostracods (72.7 percent), dipterous larvae (59.1 percent), and cladocerans (45.5 percent). Rotifers, mayfly and damselfly nymphs, Hydracarina, snails, and parasitic copepods (*Argulus*) were eaten in small numbers. These small centrarchids were completely carnivorous and served as a link between the invertebrates and larger piscivorous fishes.

Food of Invertebrates

Food habits of invertebrates which enter into the food chains must be known in order to determine their relative position in the food cycles which eventually produce piscivorous fishes. References to the general food habits of various species and groups of invertebrates are found in a number of general works (Hyman, 1951; Hungerford, 1919; Malloch, 1915; Morgan, 1930; Ward and Whipple, 1918; and others). The following invertebrates are considered to be herbivorous: Oligochaetes, some rotifers, copepods, cladocerans, fresh-water shrimp, mayfly nymphs, caddis larvae, some Hemiptera (*Corixa*), some beetles (Haliplidae), and snails. Omnivorous

forms are some rotifers, ostracods, scuds (*Hyalella*), and crayfish. Carnivorous forms include some rotifers, dragonfly and damselfly nymphs, Hemiptera, most beetles, and water mites.

The author examined the stomach contents of 49 specimens of fresh-water shrimp (*Palaemonetes paludosa*) collected at intervals between February 20 and June 10. Food eaten by this species consisted almost entirely of algae and plant fragments. Organisms identified and the percentage frequency of occurrence of each was as follows: fragments of higher plants, 100 percent; green algae, 100 percent; diatoms, 100 percent; bluegreen algae, 57 percent; animal remains, 16 percent. Animal food consisted of fragments of rotifers, copepods, ostracods, the parasitic copepod *Argulus*, chironomid larvae, snails, and fish scales. The abundance of diatoms and other algae suggests that the periphyton is the primary source of food. The fresh-water shrimp is an important converter of plant material into animal tissue.

Stomach contents of 19 mayfly nymphs (*Caenis diminuta* and *Callibaetis floridana*) consisted of a mass of finely ground green and bluegreen algae, many diatoms, and debris. Intestinal tracts of 17 damselfly nymphs (*Enallagma* sp.) contained ostracods, scuds, water mites, mayfly nymphs, and chironomid larvae. Examination of the intestinal tracts of 15 chironomid larvae revealed diatoms and masses of fine debris, apparently of plant origin.

Food Chains and the Production of Spotted Gar

It is well known that a population of piscivorous fishes is superimposed upon populations of lesser fishes and invertebrates and that these in turn are dependent for food upon a population of plants, which alone are capable of converting the basic inorganic nutrient substances into protoplasm. This dependence, direct or indirect, of fishes upon plants, particularly algae, has been emphasized by a number of biologists (Dequine, 1950; Kid, 1927; Nurnberger, 1928, 1929, 1930; Prescott, 1951; Tilden, 1929; Welch, 1952; and others). Thus the quantity of plants and the number of fishes and invertebrates which can utilize them are important factors in determining the number of piscivorous fishes which can be supported in a given situation.

In the Tamiami Canal the spotted gar constitute the ultimate consuming group under consideration, and the size of the gar population is indicative in part of the success with which the animals upon which it feeds are able to convert the available plants into animal protoplasm. Since the loss in substance is great, perhaps 90 percent in each conversion step (Hiatt, 1947), the fewer the intermediate links, the greater the gar population. Thus if we assume that 100 pounds of plant material are required to produce 10 pounds of herbivorous fishes, they in turn will produce 1 pound of gar. If two steps are required in the food chain, it will require 1,000 pounds of plant material to produce 100 pounds of herbivorous invertebrates, which will provide food for 10 pounds of small carnivorous fishes, and they in turn will support 1 pound of gar. In this study more than 60 percent of the

volume of gar food was produced directly from plants by a single step. Animals chiefly concerned with this one link in the food chain are the sailfin molly, flagfish, least killifish, eastern mosquitofish, fresh-water shrimp, crayfish, and other herbivorous invertebrates. Organisms forming about 40 percent of the gar food and produced by two or more steps in the food-conversion cycles are the redfin killifish, golden topminnow, warmouth, bluegill, spotted sunfish, and the larger carnivorous invertebrates. Although there are dozens of complexly interrelated food chains involved in the production of food organisms which are utilized by gar, these food relationships can be divided into two general categories, which are: (1) algae and plant debris → herbivorous fishes and herbivorous invertebrates → gar, and (2) algae and plant debris → herbivorous invertebrates → carnivorous fishes and carnivorous invertebrates → gar.

The underlying factors in large measure responsible for the extremely large gar population in the Tamiami Canal are: (1) the great production of plants, particularly of algae in the periphyton; (2) the abundance of fishes and invertebrates capable of converting plant material into animal tissue; (3) the economy of plant and animal protoplasm effected by the short food chains which produce food organisms suitable for gar; (4) the presence of great numbers of fresh-water shrimp and forage fish, which provide an abundance of food readily available for gar; and (5) the paucity of natural predators capable of appreciably reducing the population and the lack of angling effort directed toward the capture of these fish because of the disdain in which they are held by fishermen.

From a strictly biological point of view the food-cycle relationships in the Tamiami Canal are efficient and result in the production of a tremendous number of gar. From an economic point of view it is unfortunate that the great biological productivity of this canal culminates in an economically worthless fish currently being produced at a rate of several hundred to perhaps a thousand pounds per acre of water. If through some fish-management practice the gar population could be eliminated, an equally large population of game and pan fishes probably could be produced.

Literature Cited

American Public Health Association
1936. Standard methods for the examination of water and sewage. 8th ed. New York. 309 pp.

Barney, R. L., and B. J. Anson
1920. Relation of certain aquatic plants to oxygen supply and to capacity of small ponds to support the top-minnow (*Gambusia affinis*). Trans. Am. Fish. Soc., Vol. 50, pp. 268–278.

Bonham, Kelshaw
1941. Food of gars in Texas. Trans. Am. Fish. Soc., Vol. 70 (1940), pp. 356–362.

Coker, Robert E.
1930. Studies of common fishes of the Mississippi River at Keokuk. Bull. U. S. Bur. Fish., Vol. 45 (1929), pp. 141–225.

Dequine, John F.
1950. Lowdown on balance. Florida Wildlife, Vol. 3, No. 12, pp. 3, 17–20.

Hiatt, Robert W.
1947. Food-chains and the food cycle in Hawaiian fish ponds. Part II. Biotic interaction. Trans. Am. Fish. Soc., Vol. 74 (1944), pp. 262–280.

Hildebrand, Samuel F.
1919. Fishes in relation to mosquito control in ponds. Rept. U. S. Comm. Fish. for 1918. App. 9, pp. 1–15.
1921. Top minnows in relation to malaria control, with notes on their habits and distribution. U. S. Publ. Health Ser. Pub. Health Bull. 114, pp. 1–34.

Hubbs, Carl L., and E. Ross Allen
1943. Fishes of Silver Springs, Florida. Proc. Fla. Acad. Sci., Vol. 6, pp. 110–130.

Hungerford, H. B.
1919. The biology and ecology of aquatic and semiaquatic Hemiptera. Univ. Kansas Sci. Bull., Vol. 11, pp. 3–341.

Hyman, Libbie H.
1951. The invertebrates: Acanthocephala, Aschelminthes and Entoprocta. McGraw-Hill Book Company, New York. 572 pp.

Kidd, Patience Ellis
1927. The food of Minnesota fishes with special reference to the algae. Trans. Am. Fish. Soc., Vol. 57, pp. 85–91.

Kuntz, Albert
1914. Notes on the habits, morphology of the reproductive organs, and embryology of the viviparous fish *Gambusia affinis*. Bull. U. S. Bur. Fish., Vol. 33 (1913), pp. 177–190.

Lagler, Karl F., and Frances V. Hubbs
1940. Food of the long-nosed gar (*Lepisosteus osseus oxyurus*) and the bowfin (*Amia calva*) in southern Michigan. Copeia, 1940, No. 4, pp. 239–241.

Lagler, Karl F., Carl B. Obrecht, and George V. Harry
1943. The food and habits of gars (*Lepisosteus* spp.) considered in relation to fish management. Invest. Indiana Lakes and Streams, Vol. 2, pp. 117–135.

Malloch, J. R.
1915. The Chironomidae or midges of Illinois with particular reference to the species occurring in the Illinois River. Bull. Ill. Lab. Nat. Hist., Vol. 10, pp. 275–543.

Mellen, Ida
1927. The natural and artificial foods of fishes. Trans. Am. Fish. Soc., Vol. 57, pp. 120–142.

Morgan, Ann H.
1930. Field book of ponds and streams. G. P. Putnam's Sons, New York, 448 pp.

Nurnberger, Patience Kidd
1928. A list of plant and animal food of some fishes of Jay Cooke Park. Trans. Am. Fish. Soc., Vol. 58, pp. 175–177.
1929. Plant and animal associations in a lake. Trans. Am. Fish. Soc., Vol. 59, pp. 174–177.
1930. The plant and animal food of the fishes of Big Sandy Lake. Trans. Am. Fish. Soc., Vol. 60, pp. 243–259.

PARKER, MALCOLM V.
1939. A note on the food of the short-nosed gar at Reelfoot Lake. Rep. Reelfoot Lake Biol. Sta., Vol. 3, pp. 186–187.

PEARSE, A. S.
1918. The food of the shore fishes of certain Wisconsin lakes. Bull. U. S. Bur. Fish., Vol. 35 (1915–1916), pp. 245–292.
1922. Distribution and food of fishes of Green Lake, Wisconsin, in summer. Bull. U. S. Bur. Fish., Vol. 37 (1919–1920), pp. 253–272.

PRESCOTT, GERALD W.
1951. Algae of the western Great Lakes area exclusive of desmids and diatoms. Cranbrook Inst. Sci., Bull. 31. 946 pp.

SCOTT, WILL
1938. The food of *Amia* and *Lepisosteus*. Invest. Indiana Lakes and Streams, Vol. 1, p. 112–115.

SEAL, WILLIAM P.
1910. Fishes in their relation to the mosquito problem. Bull. U. S. Bur. Fish., Vol. 28 (1908), pp. 831–838.

SELF, J. TEAGUE
1940. Notes on the sex cycle of *Gambusia affinis affinis*, and on its habits and relation to mosquito control. Am. Midland Nat., Vol. 23, pp. 393–398.

TILDEN, JOSEPHINE E.
1929. "Plant material and debris": The algal food of fishes. Trans. Am. Fish. Soc., Vol. 59, pp. 178–187.

WARD, FERN
1931. Notes on the food and parasites of the mosquito fish (*Gambusia holbrooki*) in Florida. Trans. Am. Fish. Soc., Vol. 61, pp. 208–214.

WARD, HENRY B., and GEORGE C. WHIPPLE
1918. Fresh-water biology. John Wiley and Sons, New York, 1,111 pp.

WELCH, PAUL S.
1952. Limnology. McGraw-Hill Book Company, New York, 538 pp.

YOUNG, ORSON WHITNEY
1945. A limnological investigation of periphyton in Douglas Lake, Michigan. Trans. Am. Micr. Soc., Vol. 64, pp. 1–20.

THE WALLEYE POPULATION IN ESCANABA LAKE, VILAS COUNTY, WISCONSIN

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ABSTRACT

On Escanaba Lake, Vilas County, Wisconsin, no bag, size, or season limits have been in effect from 1946 to the present time. Large catches of walleyes from 1948 through 1950 prompted the Wisconsin Conservation Department to estimate the available stock in the lake by a tagging experiment. A total of 984 adult walleyes were tagged. In a subsequent creel census of fishermen from May 12 to October 15, 1951, 202 tagged fish were recaptured in a total catch of 1,867 walleyes. By means of the Petersen formula the population of walleyes in the lake was calculated to be 9,102 as of May 11, 1951. Even with relaxed regulations, large catches by anglers, and no stocking of the species, continued recruitment through natural reproduction has prevented undue depletion of the walleye population.

INTRODUCTION

Escanaba Lake is one of the lakes in the Northern Highlands area of Wisconsin southeast of Boulder Junction, Vilas County, which is included in the Five Lakes Project. On this group of lakes there have been no bag size, or season limits from 1946 through the present time. This project was devised to determine the effect on fish populations of regulations on size, bag, and season. A Conservation Commission order requires all persons fishing the lakes to obtain a permit and to report their catch. A checking station with attendant is located for this purpose during the summer months at Escanaba Lake. In the winter anglers get permits and return them to the Trout Lake Forestry Headquarters, 4 miles from Escanaba Lake.

Escanaba Lake has an area of 291 acres and a maixmum depth of 36 feet. The phytoplankton crop is fairly large during the summer. The methyl-orange alkalinity is 12 p.p.m. (Moyle, 1942) and bound CO_2 is 10.7 p.p.m. (Williamson, 1947).[1] The lake stratifies during the summer and during August oxygen usually disappears completely below the thermocline.

Species of fish found in Escanaba Lake are the walleye (*Stizostedion v. vitreum*), yellow perch (*Perca flavescens*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus d. dolomieui*), muskellunge

[1] Williamson, L. O., 1947, Experimental lakes project, Vilas County, Progress Report No. 1, Wis. Cons. Dep't. Invest. Rep. No. 508, 36 pp.

(*Esox m. masquinongy*) northern pike (*Esox lucius*), rock bass (*Ambloplites r. rupestris*), pumpkinseed (*Lepomis gibbosus*), bluegill (*Lepomis m. macrochirus*), and black crappie (*Pomoxis nigromaculatus*). It originally did not contain walleyes but they were established by fry stocking, (Table 1). The lake has not been stocked with any fish since 1945 or with walleyes since 1942.

TABLE 1.—*Numbers of walleye fry planted in Escanaba Lake*
[The total number for the 10 years was 5,060,378]

Year	Number	Year	Number
1933	103,150	1938	525,122
1934	94,736	1939	200,000
1935	188,850	1940	1,627,900
1936	596,600	1941	1,100,000
1937	496,020	1942	128,000

In 1946 the fish population of Escanaba Lake was intensively sampled by use of fyke nets; 336 net days produced 1,010 pounds of fish. During these operations only 32 walleyes were caught. During the 1947 walleye spawning season fyke nets caught 97 walleyes. For the size and age of these fish refer to Table 2 (Williamson, 1947—see footnote 1). A summary of the creel-census records from 1946 to 1951 is given in Table 3. The catch of walleyes by anglers was very poor until the summer of 1948.

In the 1947 creel census an abundant year class began to show (Threinen, 1950),[2] and in the following year the summer catch jumped to 4,003 walleyes, mostly members of age-groups I and II. These two strong year classes contributed to the large harvest not only of that year but also of later years. In 1950, 5,716 walleyes were caught. In that year and in 1951 another year class of walleyes (hatched in 1949) entered the catch in addition to the 1946 and 1947 year classes.

TABLE 2.—*Age and length of walleyes caught in fyke nets during the spawning season of 1947*
(From Williamson 1947]

Age group	Males		Females	
	Number	Average length (inches)	Number	Average length (inches)
III	1	17.0	..	....
IV	17	18.8	6	21.3
V	26	21.1	13	22.9
VI	6	23.3	..	....
VII	17	24.3	..	....
VIII	1	24.5	4	28.1
IX	..	....	4	29.5
X	..	....	1	29.5

[2] Threinen, C. W., 1950, Changes in the creel and fishing success as brought out by a five year creel census. Wis. Cons. Dept., Invest. Rep. No. 801, 9 pp.

TABLE 3.—*Creel census for Escanaba Lake, 1946-1951*

Season and year	Man hours	Fish per man hour	Number of fish caught				
			Walleye	Perch	Smallmouth bass	Largemouth bass	Rock bass
Summer 1946	6,254	0.74	2	3,449	635	167	240
Winter 1946-47	3,132	1.71	2	5,354	...	...	...
Summer 1947	5,677	1.09	38	5,287	421	52	305
Winter 1947-48	618	1.37	9	834	...	...	...
Summer 1948	9,403	0.95	4,003	4,229	385	53	217
Winter 1948-49	3,373	2.36	310	7,642	...	...	...
Summer 1949	17,562	0.52	1,930	6,256	540	62	233
Winter 1949-50	1,770	0.59	269	772	...	....	....
Summer 1950	35,166	0.22	5,716	1,140	191	49	380
Winter 1950-51	696	0.26	171	7	...	...	...
Summer 1951	19,740	0.16	1,867	644	57	21	336

Marking Study

In 1951 plans were made to tag a number of walleyes in Escanaba Lake to study the rate of exploitation, the natural mortality, and the size of the population. This paper is concerned with the population estimate of walleyes in Escanaba Lake on May 11, 1951, the rate of exploitation of the walleye population from May 12 through October 15, 1951, and the large harvest of walleyes which were produced through natural reproduction.

A total of 948 adult walleyes were tagged from the net catches of four 1-inch-mesh fyke nets set in Escanaba Lake from May 3 to May 11 during a portion of the spawning period of these fish. Figure 1 gives the length-

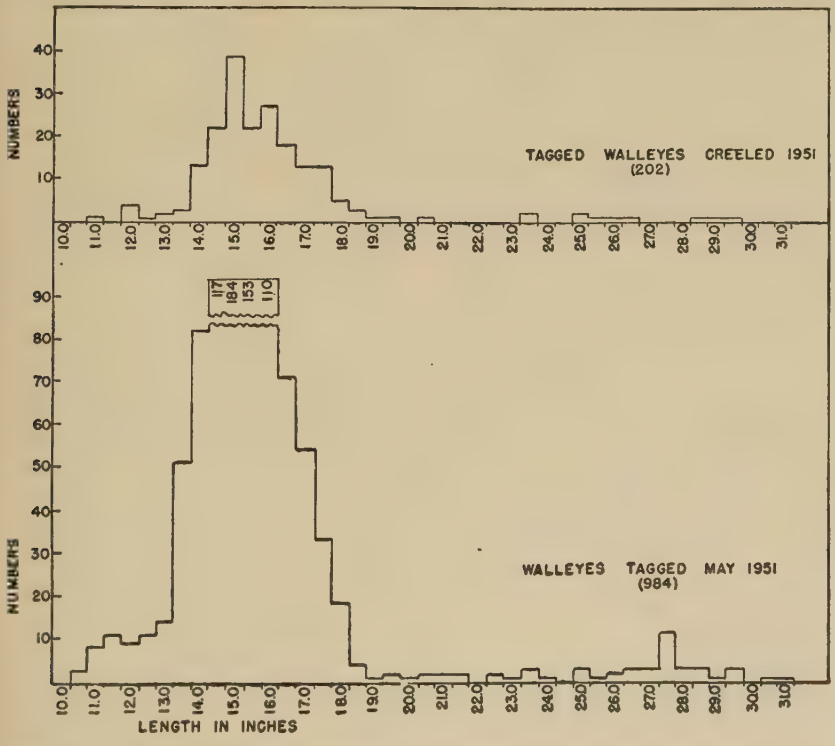

Figure 1.—Length frequency distribution of walleyes tagged and recaptured in 1951.

frequency distribution of the walleyes which were tagged, and the length frequency of the tagged walleyes recaptured.

All fish ranging from 10.5 to 24.0 inches (total length) were tagged with a No. 3 steel tag 1 7/16 inches in length. Walleyes over 24.0 inches were tagged with an aluminum tag 2.0 inches in length. The tags were attached

in the corner of the upper jaw. Each tag was stamped with "WCD" and a number. Total length, number of tag, and sex of fish were recorded for each fish tagged and scale samples were taken for subsequent determinations of age and rate of growth. No effort was made to distribute the tagged fish uniformly about the lake in order to increase the chances of random sampling because of the belief that during and after spawning the walleyes move about freely and that the uniform dispersal of tagged fish is not so essential as in certain fishes, particularly the centrarchids. Of the 984 fish tagged, one was found dead shortly after tagging and returned to the Trout Lake Forestry Headquarters by a fisherman. Therefore, all calculations are based on the assumed presence of 983 tagged walleyes on May 12 after which date fishermen began to catch a few walleyes. The population estimate is based on the number of tagged and untagged fish caught from May 12 to October 15, 1951.

The method used for estimating the population is based on the procedure originally employed by Petersen (1896). Ricker (1948) described the various procedures for estimating fish populations and commented on the mathematical implications of the Petersen method. If the total number of tagged walleyes is N, and the number of tagged ones recaptured R, then it follows that, within limits of sampling error, the rate of exploitation (r) of the population is described by the equation:

$$r = \frac{R}{N}$$

Further, if the total catch is H, the population estimate is

$$P = \frac{H}{r} = \frac{NH}{R}$$

The total number of tagged walleyes (N) was 983; the number of tagged ones recaptured (R) from May 12 to October 15 was 202; the total catch during the same period (H) was 1,867.

The ratio of marked to unmarked yellow walleyes in the sample is first estimated as $\frac{202}{1,867} = 0.108$ and by reference to Clopper and Pearson's (1934) chart the limits of confidence of the ratio are found to be 0.09 — 0.12. By means of Petersen's formula the number of fish in the population is now calculated as $P = \frac{HN}{R} = \frac{983}{0.108} = 9,102$. By substituting for 0.108 its two limits, the possible range of P for 95-percent confidence is estimated as $\frac{983}{0.09} = 10,922$ to $\frac{983}{0.12} = 8,192$. Therefore, the walleye population of Escanaba Lake on May 11, 1951, is estimated to have been 9,102 with the upper limit of estimate 10,922, and the lower limit of estimate 8,192.

Finally, the rate of exploitation is $r = \frac{R}{N} = \frac{202}{983} = 0.205$.

Obviously, H, N, and R, are all subject to systematic error. It is assumed

that the effects of tagging and handling on survival were negligible, and that the ratio of tagged to untagged fish in the census represented the true ratio in the lake. The greatest possibility for error probably lay in the number of tagged fish caught. There was no checking station attendant at the project until May 19. However, a Department employee was at Escanaba Lake almost every day from the time tagging began until May 19 and all fishermen seen were requested to watch carefully for tagged fish. Of course, fishermen were compelled by law to report all catches. From May 19 to October 15 an attendant was at the checking station on Escanaba Lake. For the first part of the season the attendant left in the evening, but later on stayed all night at the project. The possibility exists also that fishermen overlooked a few tagged fish, especially late at night. Therefore, the number of tagged fish reported caught is undoubtedly somewhat low, and the population estimate is correspondingly too large.

Effects of Tagging

Practically all of the tagged fish caught in 1951 showed no evidence of irritation around the tag.

On May 1 and 2, 1952, fyke nets were set in Escanaba Lake to catch a portion of the spawning walleyes. A total of 47 tagged fish were caught in three fyke nets in 2 days. Two of the tagged fish showed evidence of irritation and one 26-inch walleye was captured that had lost its tag. During these netting operations records were obtained of the growth of the tagged fish (Table 4).

Threinen (1950—see footnote 2) studied the growth rate of walleyes captured in Escanaba Lake from 1947 through 1950. Fifteen 2-year-old walleyes were on the average 3.4 inches longer than 15 yearling walleyes. Fifteen 3-year-old walleyes were on the average 2.2 inches longer than fifteen 2-year-old fish and ten 5-year-old walleyes were on the average 3.9 inches longer than ten 4-year-old fish. Although the condition of the tagged fish appeared good, comparisons of the growth of tagged fish with the rate of increase of untagged fish indicate that the tags exerted a retarding influence on growth.

Exploitation and Stocking

The rate of exploitation indicates that 20.5 percent of the tagged walleyes were caught from May 12 through October 15, 1951. Since it is assumed that untagged walleyes were caught in the same proportion, the harvest in this one year was not heavy.

Escanaba Lake was originally a smallmouth bass lake and walleyes were introduced by the stocking of fry. A comparison of the stocking records with the data on age composition of fish caught in 1947 (Table 2) and with the creel-census records for 1946–1947 (Table 3) makes it apparent however, that these plantings did not give rise to any abundant year classes.

TABLE 4.—*Growth of tagged walleyes recaptured after a period of approximately a year*

Tag number	Total length (inches)		Growth (inches)
	At time of tagging (May 3-11, 1951)	At time of recapture (May 2-3, 1952)	
A1109	27.4	27.4	0.0
1286	16.0	16.4	0.4
1341	14.7	15.4	0.7
1178	13.8	14.3	0.5
1530	13.4	13.7	0.3
1138	14.6	14.9	0.3
1338	18.2	18.4	0.2
1707	16.4	17.2	0.8
1706	16.1	16.5	0.4
1410	14.0	14.5	0.5
1054	15.4	15.6	0.2
1173	15.0	15.4	0.4
1148	14.8	15.3	0.5
1487	14.7	14.8	0.1
1449	15.4	15.9	0.5
1124	14.7	15.3	0.6
1246	15.6	15.9	0.3
1708	13.2	13.7	0.5
1243	13.5	13.7	0.2
2550	16.1	16.3	0.2
1749	13.6	13.7	0.1
1197	15.4	15.8	0.4
2598	14.2	14.7	0.5
2678	13.4	13.8	0.4
1003	16.3	16.5	0.2
1668	16.2	16.3	0.1
1612	15.1	15.6	0.5
1142	14.1	14.6	0.5
1252	14.6	15.0	0.4
1423	13.9	14.0	0.1
1293	16.4	16.7	0.3
1276	14.1	14.4	0.3
1688	14.0	14.2	0.2
1459	13.9	14.0	0.1
1513	13.7	13.9	0.2
2539	14.3	14.9	0.6
1651	16.7	16.4	−0.3
1079	15.2	15.5	0.3
1224	14.7	14.9	0.2
1630	15.0	15.2	0.2
1719	14.7	15.5	0.8
1438	15.5	16.0	0.5
2653	15.0	15.3	0.3
1177	15.8	16.2	0.4
1655	15.6	16.1	0.5
1523	14.9	15.3	0.4
1549	16.2	16.5	0.3
Average			0.33

Natural reproduction of the walleye produced large year classes in 1946, 1947, and 1949. Although fishermen caught 12,379 of these walleyes (Table 3) from 1948 until the ice left the lake in 1951, there was still a population of from 8,192 to 10,922 walleyes of spawning size in the lake on May 11, 1951. These figures demonstrate clearly the great effectiveness of natural reproduction of the walleye in maintaining the popula-

tion in Escanaba Lake. Even with removal of size, season, or bag limits, heavy fishing pressure, and catching of many fish by anglers, the remaining stock of walleyes is still sufficient to provide future abundant year classes and many more fish for the angler.

Literature Cited

Clopper, C. J., and E. S. Pearson
1934. The use of confidence or fiducial limits applied to the case of the binomial. Biometrika, Vol. 26, pp. 404–413.

Moyle, John B.
1945. Some chemical factors influencing the distribution of aquatic plants in Minnesota. Am. Midland Nat., Vol. 32, pp. 402–420.

Petersen, C. G. J.
1896. The yearly immigration of young plaice into the Limfjord from the German Sea, etc. Rept. Danish Biol. Stat., Vol. 6 (1895), pp. 1–48.

Ricker, W. E.
1948. Methods of estimating vital statistics of fish populations. Indiana Univ. Pub., Sci. Ser. No. 15, 101 pp.

TECHNIQUE FOR THE APPLICATION OF A STREAMER-TYPE FISH TAG

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ABSTRACT

Principal features of the technique are: attachment of the plastic tag by means of a nylon-thread loop prepared in advance of field work; use of a curved surgical needle with cutting edge and a split eye for application of the tag. The procedures for splitting the needle's eye and for applying the tag are described and illustrated by a series of photographs.

Because of the valuable information that can be gained only by marking-and-recovery experiments, new or improved methods of marking are of continuing interest to fishery biologists. A mark, to be satisfactory, must be easily visible and readily identifiable and must, of course, do a minimum of injury to the fish bearing it. For certain type of studies fin-clipping has proved adequate, but where the situation calls for the identification of individual fish we face the problem of devising a suitable numbered tag.

Many different kinds of tags have been developed for marking fish. An appraisal of the merits of the various tags or even a listing of the principal types would be to no point here in view of the availability of comprehensive information in publications by the International Council for Exploration of the Sea (1932) and Rounsefell and Kask (1945). Rather, the present brief article is concerned only with the description of a procedure that should make easier the field application of the streamer type tag.

The streamer tag with which this article deals is of the Atkins type defined by Rounsefell and Kask (1945) as a "loose plate (or bead) attached by a wire or thread that pierces the tissues." (Those authors reviewed a number of experiments with different kinds of Atkins tags.) Possibilities for successful use of this type of tag were increased greatly by the development of modern plastic materials. Not only has the use of plastic reduced the weight of tags and ended the problem of corrosion of metallic parts; nylon thread has provided a strong durable material for attachment, long-lived and supple.

Because of evidence that the smaller fish were unable to survive tagging with strap tags on the operculum, or lost the tags, and because of the almost complete failure of fin-clipping as a means of tracing the movements of yellow perch, *Perca flavescens* (Mitchill), in Green Bay[1] (Mraz,

[1] The studies of migration of the Green Bay perch were part of investigations carried out cooperatively by the Fish and Wildlife Service and the Wisconsin Conservation Department.

1952), it was decided to try a streamer tag consisting of a plastic plate attached to the fish by means of a nylon thread. This decision was influenced strongly by reports of good success with this mark in studies by investigators of the University of Toronto and the Ontario Department of Lands and Forests of movements of fish in northern Lake Huron. It was necessary first to work out a procedure adapted to the tagging of large numbers of fish under the rather difficult conditions of field work in southern Green Bay. Much time is lost in running to and between net stations and in lifting and resetting gear. Furthermore, the actual tagging frequently must be carried out with the small boat at anchor in a rough sea and at temperatures which do not make for great nimbleness of wet fingers. Not to be ignored either is the considerable daily cost of hiring commercial fishermen and chartering a boat and gear.

Through the use of the technique of tagging as finally worked out and as described in the following paragraphs, we marked and maintained individual records (length, tag number, tagging station, and date) of as many as 2,600 yellow perch in a single day with a six-man crew—three taggers, one recorder, one "neddle-threader," and one fish handler.

The tag (Fig. 1) consists of an oval plastic plate ½ inch long, 5/16 inch wide and between 0.02 and 0.03 inch thick. A circular 0.06-inch hole is centered 0.06 inch from the edge of one of the ends. Letters and numerals are protected from erosion by lamination with transparent plastic. The technique that makes possible the large-scale use of the tag depends on the attachment of nylon-thread loops to the tags before the start of field work (thus avoiding the necessity of tying knots in the field) and in the use of a surgical needle with a split eye for the actual application of the tag to the fish.

To prepare the tags for use 3½-inch pieces of thread are cut and tied and then attached to the tags as shown in Figure 1. For the perch tagging the thread was No. 69 "Nylock" nylon gill-net twine (tensile strength, 9 pounds). Smaller thread can be used but is more difficult to handle in the field.

The needles used (Fig. 1) were Anchor Brand Stainless Surgical Needles, ⅜ circle cutting edge, number 1822-10. Needles with cutting edges are desirable because they pass through the scales readily whereas round needles tend to force one or two scales through the flesh as they penetrate it. In addition to causing unnecessary injury to the fish, these scales remain near the point of the needle and make the tagging operation more difficult.

The posterior end of the eye of the needle was split by use of a dental drill and a saw-blade of 0.002-inch bronze shim stock (Fig. 2). This saw-blade, which is of approximately ⅜-inch diameter, will usually cut at least two or three needles before it becomes too small for further use. The splitting of the eye at first is rather difficult, but after some practice, the cutting becomes a simple task. By making the cut from the outer edge of the curved needle, a V-shaped opening is obtained that greatly facilitates the operation of threading the needle. To make the cut through the needle,

FIGURE 1.—Plastic tag, nylon-thread loop, and surgical needle employed in tagging.

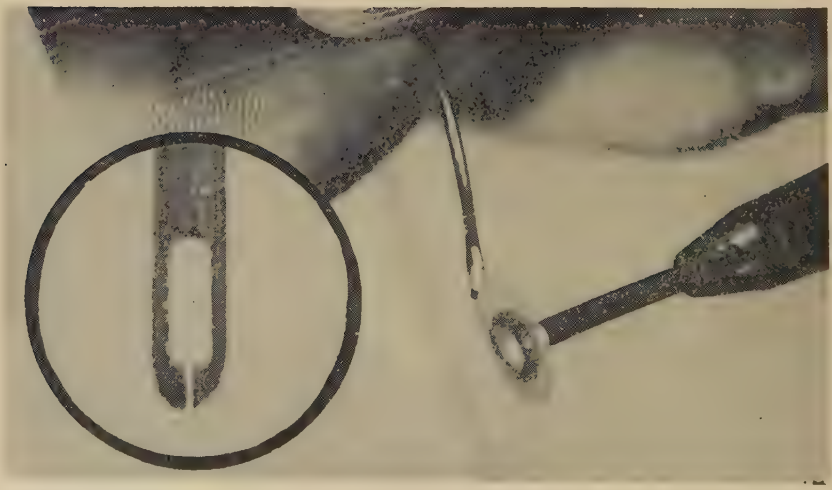

FIGURE 2.—Saw used to split the eye of the surgical needle, and eye of needle (insert) after the split has been completed.

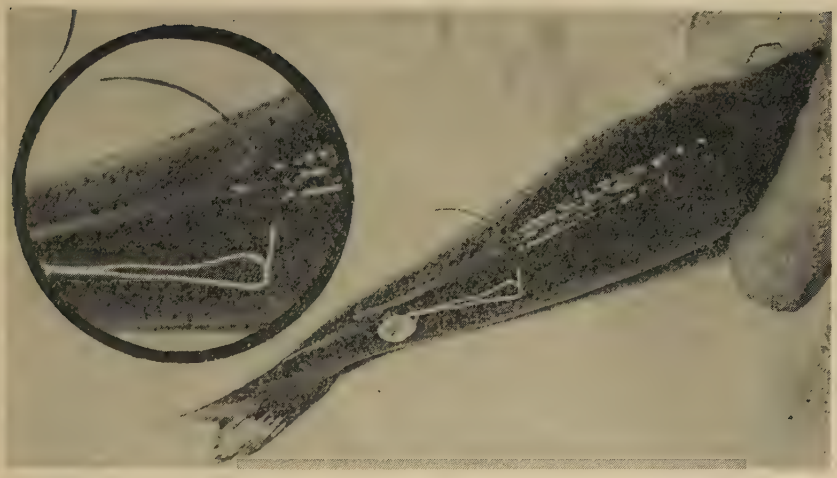

FIGURE 3.—First step in tagging; needle has penetrated through flesh of fish.

FIGURE 4.—Hole in tag has been passed over point of needle.

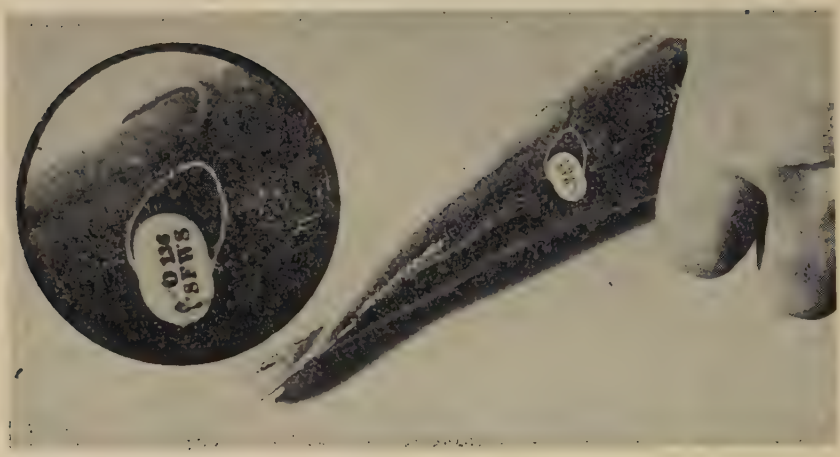

FIGURE 5.—Needle and thread have passed through hole in tag and thread has been looped over tag.

FIGURE 6.—With needle detached and tag pulled tight, fish is ready for release.

the saw and needle are held as shown in Figure 2. A thin layer of fine valve-grinding compound in oil is applied to the saw blade and another drop of oil and grinding compound is applied to the eye of the needle. The sawing operation is then started by holding the rapidly revolving saw blade, under light pressure, in contact with the needle eye (Fig. 2). This pressure is released every 40 to 50 seconds in order that the oil and grinding compound can move into the newly formed kerf. After a few minutes of cutting, the operator can determine for himself the amount of pressure to be applied. If too much pressure is used, the blade will be destroyed. Occasionally the saw blade should be sharpened by applying it to a fine whetstone. Sharpening is most important just before the cut is completed. If the blade's cutting edge is too thick, the opening in the needle's eye will be too wide and will not hold the thread firmly. The sawing usually polishes the sides of the eye sufficiently so that the nylon thread used on the tag passes through the slit in both directions without being frayed. If the opening is too small and damages the thread as it is passed through it, the needle should be polished lightly with a sharp saw blade. The saw should be used as little as possible after the cut has been completed because the width of the cut is rapidly expanded and the needle will soon fail to hold the thread firmly. Occasionally a needle, made of steel softer than usual, will be very difficult to cut because the saw blade is worn down by the grinding compound instead of cutting the needle. Under normal conditions, the particles of grinding compound are embedded slightly into the soft bronze and moved across the hard needle surface.

In the tagging operation the loop of the thread is placed in the eye of the needle (Fig. 1) and the needle is passed through the fish (Fig. 3) and the small hole in the tag passed over the tip of the needle (Fig. 4). The needle and the excess thread are pulled through the hole in the tag and looped back over the tag (Fig. 5). The needle is then detached gently from the thread. The tag is pulled tight and the fish (Fig. 6) is ready to be released. After some practice, the average individual can tag a fish rather rapidly. On several of these tags which were recovered after being on a fish for about one year the thread showed no wear and its breaking strength was not noticeably changed.

Literature Cited

International Council for the Exploration of the Sea
1932. A guide to fish marks used by members of the International Council for the Exploration of the Sea, and by some non-participant countries. Jour. du Cons., Vol. 7, pp. 133–165.

Mraz, Donald
1952. Movements of yellow perch marked in southern Green Bay, Lake Michigan, in 1950. Trans. Am. Fish. Soc., Vol. 81 (1951), pp. 150–161.

Rounsefell, George A., and John Lawrence Kask
1945. How to mark fish. Trans. Am. Fish. Soc., Vol. 73 (1943), pp. 320–363.

VITAL STATISTICS OF THE FISH POPULATION OF GORDY LAKE, INDIANA [1]

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ABSTRACT

The fishing, populations, and mortality rates of fishes in Gordy Lake, Indiana, were studied in 1950 by creel-census and mark-and-recapture techniques. Gordy Lake has an area of 28.5 acres and a maximum depth of 35 feet.

The total number of fish caught by all methods of fishing from June 2 to September 4 was 4,012 which weighed 722.5 pounds. Bluegills (*Lepomis macrochirus*) constituted 81.5 percent of the total yield which amounted to 25.4 pounds per acre of water surface. Cane-pole fishermen caught 15.2 fish (2.72 pounds) per 10 pole-hours.

Populations of the most important species were measured by at least two of the following independent methods of estimation: (1) Schnabel estimate based on trap-caught fish; (2) Schnabel estimate based on fish caught by fishermen; (3) Petersen estimate based on the fish caught by fishermen after trapping ceased; (4)DeLury estimate based on catch-effort statistics of traps. The total standing crop of legal-sized (5 inches or longer, total length) bluegills was 7,900 or 1,320 pounds. Legal-sized redear sunfish (*Lepomis microlophus*) numbered about 600 individuals weighing 105 pounds. Legal (10 inches or longer) largemouth bass (*Micropterus salmoides*) were estimated at about 100-300 fish, or 88–270 pounds. Warmouth (*Chaenobryttus coronarius*), pumpkinseeds (*Lepomis gibbosus*), and green sunfish (*Lepomis cyanellus*) of legal size numbered about 550 fish weighing 63 pounds. The total standing crop of all species, including those not mentioned, was estimated to be 78 pounds per acre.

The total annual mortality of bluegills was judged to be 82 percent of which exploitation by anglers accounted for 35 percent. The yearly rate of exploitation of redear sunfish was estimated as 29 percent and the total annual mortality rate 69 percent. Largemouth bass were exploited at a rate of about 36 percent per year and the total annual mortality rate was estimated to be 60 percent. Some mortality rates of the minor species are given.

As nearly as can be judged by published information, Gordy Lake represents about the average condition with respect to yield, catch per unit effort, and standing crop to be expected on Indiana lakes of this type.

INTRODUCTION

The fish population of Gordy Lake was studied as a part of a program prosecuted to learn some of the general characteristics of populations subjected to varous intensities of sport fishing. Similar studies of other northern Indiana lakes have previously been reported by Ricker (1942, 1945a)

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and Gerking (1950). These investigations have shown that sport fishing is not, in general, deleterious to naturally reproducing populations of panfish, and have been instrumental in establishing a year-round open season on these fish in Indiana. This study was made 2 years after the seasonal limitations for panfish fishing had been eliminated. No evidence was found that panfish populations have declined as a result of increased fishing pressure.

The Gordy Lake investigation may also be of interest because (1) it provides another complete description of the summer fishing in a lake, (2) the abundance of a part of the population was measured by Schnabel (1938) and Petersen (1896) type estimates and confirmed by the method of DeLury (1947), (3) measures of total mortality, rate of exploitation, and natural mortality are presented, and (4) the data were obtained from a lake which, by Indiana standards, is about average as to fishing pressure, catch per unit effort, and yield. Most of the results of this investigation agree with similar work which has been done on other waters.

Before beginning the discussion of the data, the author wishes to make a statement of opinion about fish population studies. A number of population estimates have already been made with fishes, and it is likely that the number will increase rapidly in the future. Objections, voiced and unvoiced, have been made against the methods which are now available for these studies, and even the writer was not and still is not convinced that the variable, unpredictable, and unknown factors of fish behavior have been taken sufficiently into consideration. In the present state of knowledge, however, the writer is convinced that populations can be estimated with an accuracy sufficient to answer most present-day fishery problems. The mechanics of carrying out a fish population study are not to be taken lightly. Research of this sort requires the greatest attention. A fish population problem should be handled as carefully as a controlled laboratory experiment. In fact, it probably should be conducted even more carefully because of the uncontrollable elements affecting the capture, marking, and handling of the fish and their subsequent behavior. Methods of estimating fish populations on relatively large bodies of water have not developed to the point where a short visit at a lake is sufficient to obtain reliable information.

Description of Gordy Lake

Gordy Lake is located in the southwestern part of Noble County in the lake district of northern Indiana. It is one of a group of nine lakes known locally as the Indian Village Chain. These lakes drain northwestward into Lake Wawasee. Gordy Lake is oval-shaped with a small inlet on the northeastern shore and a small outlet on the northwestern shore. Both inlet and outlet are heavily vegetated and show very little flow except during periods of exceptional rainfall. The lake has an area of 28.5 acres and a maximum depth of 35 feet. In 1950 a thermocline developed between 13 and 26 feet. The narrow, heavily-vegetated littoral area drops off steeply about 10-30

feet from shore. Hile (1931) sampled the fish of Gordy Lake for growth study and took ciscoes (*Coregonus artedii*) in gill nets, an unusual occurrence for so shallow a lake. Experimental gill-netting in Gordy Lake by the Indiana Lake and Stream Survey took 10 ciscoes in 1951 and one cisco in 1952.

The lake is accessible from two points. One is at a Scout Camp which keeps no permanent supply of boats and which is active only 2 weeks in the summer. The other access is controlled by a farmer who operates a boat rental. These circumstances made it possible to check the fish caught by practically all fishermen. Less than 2 percent of the anglers were missed during the summer.

Plan of the Investigation

The populations and other vital statistics of Gordy Lake fishes were investigated mainly by mark-and-recapture methods. The fish were caught in cylindrical wire traps about 4 feet long and 2.5 feet in diameter with a funnel in only one end. The traps were fished from June 2 to July 15. Each day the unmarked fish caught were marked and all fish returned to the water in the general vicinity of the trap. The fish of less than legal length, (5 inches total length for panfish and 10 inches for largemouth bass) were marked by removal of the right pectoral fin and those above legal length were marked by removal of the left pectoral fin. The traps were scattered around the periphery of the lake in order to distribute the marked fish throughout the whole lake. The traps were fished in one place no longer than 2 days, and they were usually moved a short distance each day. Fork length in millimeters, weight in grams, and type of mark (if any) were recorded for each fish captured. The usual creel-census procedures were followed. The same observations as described above were made on the fisherman's catch. Fishing for bluegills and other panfish in Indiana is carried out the year-round, so that fishing was being done while marking was in progress.

Three, and under certain conditions four, independent estimates of abundance were possible by the plan of the investigation: (1) a Schnabel type estimate was made based on trap-caught fish (since fishing and trapping occurred at the same time, it was necessary to subtract the recaptures taken by fishermen from the day-to-day totals of marked fish present in the lake); (2) another Schnabel type estimate was made based on angling records kept from June 2 to the end of the observational period, September 4; (3) a Petersen type estimate was made through the use of fishing records taken after marking ceased; (4) for redear sunfish, which were extremely vulnerable to trapping, DeLury's method of estimating abundance from day-to-day values of catch per unit effort was used.

A full review of the systematic and sampling errors which may enter Schnabel and Petersen estimates has been provided by Ricker (1948). Ricker (1948), Schaefer (1951), and DeLury (1951) have discussed the

formulas and the necessary assumptions used in making these two types of estimates.

The relatively long trapping period was advantageous for making population estimates in some respects and it was disadvantageous from other points of view. The month and a half which elapsed between the beginning and end of marking was sufficient time to allow recruitment of fish into the legal-size range due to growth during the trapping period. Recruitment is recognized as a possible source of error which would influence both the Petersen and Schnabel estimates. The effects of recruitment were overcome partially by the use of length boundaries which were adjusted periodically to keep pace with the growth of the fish (this procedure is illustrated later in the paper). A month and a half is also enough time to allow some natural mortality among the marked fish. In the Petersen method where estimates are based on marked fish examined after marking ceases, this systematic error due to natural mortality would result in estimates which are somewhat larger than the true population. However, no correction has been made for natural mortality in these estimates. Loss of fish from any cause results in a decreasing population. The Schnabel method estimates a population value which lies between the two extremes. Natural mortality of marked fish affects the Schnabel estimates by making them too great. Apparently this systematic error is counteracted by the effect of the actual decrease in population size, resulting in an estimate which is closely comparable with the Petersen method. Actually these two types of estimates agree remarkably well in this and other Indiana studies. The long trapping period was advantageous because it insured ample time for both a satisfactory Schnabel estimate based on trap-caught fish and the DeLury type estimate based on catch-effort statistics.

DeLury's method has not received wide use in fishery investigations. Omand (1951) employed it successfully on some species in an extensive netting program on three lakes, but in no case did his netting encompass a whole lake and the whole population was therefore not sampled. Omand did show the applicability of the method, however. The advantage of our experiment is that the whole population of redear sunfish in the lake presumably was sampled and it was possible to check DeLury estimates with the other independent estimates listed above. The conditions which must be met in order to expect reasonable success by DeLury's method are: (1) fishing must be efficient enough to catch a considerable portion of the population; (2) the population to be sampled must be restricted so that effects of migration are negligible; (3) sampling must be done in a relatively short time so that natural mortality will not influence the results; (4) the traps or other fishing devices must not compete with one another; (5) catchability must remain constant.

The first two conditions necessary for success in estimating populations by DeLury's method seem to have been met satisfactorily by the trapping of redear sunfish. Fish caught by fishermen from two lakes below Gordy Lake in the chain were inspected and no marked fish were observed. The

unknown amount of natural mortality influences the results, but no correction has been made for this factor. The fourth condition seems to have been met since only 6 to 8 traps were used, and these were placed at least 300 to 400 feet apart. There is no satisfactory way of knowing whether catchability remain constant during the space of even 3 or 4 days. The larger redear sunfish evidently moved out of shallow water during the last third of the trapping period and thus became less catchable. This portion of the catch was eliminated from the analysis in order to overcome the difficulty.

Fishing Success

The creel census on Gordy Lake was practically complete for the period June 2 to September 4. Most abundant in the catch were bluegills and redear sunfish. A record of the catch of these two species by cane-pole fishing is found in Table 1. The catch was broken down into approximately 2-week intervals in order to reveal any fluctuations in fishing success

Table 1.—*Number and weight (pounds) of bluegills and redear sunfish caught by cane-pole fishing on Gordy Lake during the summer of 1950*

Date	Bluegills		Redear Sunfish	
	Number	Weight	Number	Weight
June 2–15	572	91.9	50	10.7
June 16–30	404	72.2	29	4.9
July 1–15	513	71.9	29	4.1
July 16–31	941	152.1	47	7.7
August 1–15	458	71.4	85	13.4
August 16–September 4	489	99.3	41	8.4
Totals	3,377	558.8	281	49.2
Average weight	.....	0.165	.....	0.175
Number caught per 10 pole hours	13.3	.....	1.1	.....

throughout the summer. The total catch of bluegills and catch per unit effort (20.2 bluegills per 10 pole hours) were greater between mid-July and August 1 than during any other corresponding period. The catch per unit effort varied between 8.7 and 12.9 fish per 10 pole hours during the other periods. The catch of redear sunfish varied from 29 to 35 fish for the several 2-week periods, and did not show a corresponding increase during the late-July period.

The catch of bluegills greatly exceeded that of redears; 3,377 bluegills weighing 558.8 pounds were caught by cane-pole fishing, but only 281 redear sunfish weighing 49.2 pounds were taken by the same method. To these figures can be added a few caught by fly fishing, making the totals 3,525 bluegills with a total weight of 589.6 pounds and 285 redears weighing 49.9 pounds. The catch of bluegills was 13 times as great in numbers and about 12 times as great in weight for the same amount of effort.

To the above totals can be added 75 fish weighing 9.4 pounds which consisted of warmouth bass, green sunfish, and pumpkinseeds, all caught principally by cane-pole fishing. Fifty-five largemouth bass were caught; their total weight was 48.9 pounds. The majority were taken by plug casters. Other fish taken included 5 golden shiners (*Notemigonus crysoleucas*), 0.6 pound; 38 yellow perch (*Perca flavescens*), 6.1 pounds; 23 black crappies (*Pomoxis nigromaculatus*), 6.5 pounds, 3 brown bullheads (*Ameiurus nebulosus*), 2.1 pounds; 1 yellow bullhead (*Ameiurus natalis*), 0.3 pound; 2 bowfin (*Amia calva*), 9.1 pounds.

The total number of all fish caught by all methods of fishing from June 2 to September 4 was 4,012 weighing 722.5 pounds. The total yield was 25.4 pounds per acre of water surface of which 81.5 percent was composed of bluegills. This yield is about average for the other Indiana lakes which have been investigated (Ricker, 1942, 1945a; Gerking, 1950). The quality of fishing on Gordy Lake in comparison to other lakes in Indiana was better than average with respect to cane-pole fishing, which is the principal method: 15.2 fish of all species with a total weight of 2.72 pounds were caught per 10 pole-hours. This take is roughly 4 fish per 10 pole-hours better than the average for all Indiana lakes reported to this time. Fly fishing was relatively poor. Only 5.7 fish were caught per 10 pole-hours. The same was true for plug casting (1.7 fish per 10 pole-hours).

Population Estimates of Redear Sunfish

The redear sunfish was first reported in northern Indiana by Kirsch (1895) at which time it apparently was not widely distributed in the northern lakes. According to the Annual Reports of the Indiana Department of Conservation, redear sunfish were first propagated successfully in 1928 at the Tri-lakes Hatchery near Columbia City. The 1928 Report shows that 12,700 fingerlings were distributed to 19 lakes and one stream in northern Indiana. The redear subsequently has been a common hatchery fish and plantings have been made extensively throughout the state. The species seems to have found most success in the natural lakes, and at the present time they probably are established in a majority of them. In every lake in which the redear sunfish has been found along with the bluegill, the redear has occupied a subordinate position. Nevertheless, redear sunfish are popular with many sportsmen because they reach a relatively large size.

Table 2 shows the length-frequency distribution of the redear sunfish of different ages whose scales were examined, along with more or less arbitrary boundaries which were established between the age groups. These data were employed for the estimation of the age composition of samples from which no scale collections were made. The age boundaries were advanced 5 millimeters each 2 weeks in order to keep pace with the growth of the fish, thereby partially eliminating the distorting effects of recruitment. Since scales were not collected during the early weeks of the investigation,

it was necessary to project the growth rate determined from these data back to the earlier part of the summer. As is usual among panfishes the length distributions of successive age groups overlap widely, but our method seems

TABLE 2.—*Length-frequency distribution of redear sunfish whose age was determined*

[Scales were taken from fishermen's catch. The dotted line represents the legal length limit. The solid lines represent the length boundaries selected for each age. No II-group fish caught July 15-31: No V-group fish taken August 1-15]

Fork length (millimeters)	Age group									
	II		III			IV			V	
	Aug. 1-15	Aug. 16-Sept. 4	July 15-31	Aug. 1-15	Aug. 16-Sept. 4	July 15-31	Aug. 1-15	Aug. 16-Sept. 4	July 15-31	Aug. 16-Sept. 4
108–112	..	..	..	..	..	..	..	..	..	..
113–117	..	1	..	..	..	..	..	..	..	..
118–122		3	..	..	..	..	..	..	..	..
123–127	1	1	4	1	3	..	..	..	..	..
128–132	1	2	2	4	..	..	..	..	..	..
133–137	1	..	3	3	4	..	1	..	..	..
138–142	..	..	3	9	2	..	..	..	..	..
143–147	..	..	1	2	4	1	1	..	..	..
148–152	..	..	1	..	3	..	2	..	..	..
153–157	..	..	1	2	5	..	1	..	..	..
158–162	..	..	1	2	1	..	3	..	..	..
163–167	..	..	..	..	..	..	2	..	..	..
168–172	..	..	..	..	..	..	1	..	..	..
173–177	..	..	..	..	..	..	2	..	..	..
178–182	..	..	..	..	..	..	..	..	..	..
183–187	..	..	..	..	..	..	..	1	..	..
188–192	..	..	..	..	..	1	..	..	..	1
193–197	..	..	..	..	..	..	..	..	..	1
198–202	..	..	..	..	..	..	..	..	1	1
203–207	..	..	..	..	..	..	..	..	..	2
208–212	..	..	..	..	..	..	..	..	..	..
213–217	..	..	..	..	..	..	..	..	..	..
218–222	..	..	..	..	..	..	..	..	..	1
223–227	..	..	..	..	..	..	..	..	..	1

to compensate fairly well for this overlap. For example, it is shown in the table that 8 age III-group fish were included among the IV-group fish and 7 IV-group fish were placed in the III-group.

A detailed treatment of the estimate of the abundance of III-group fish will be presented in order to show the methods of calculation and some of the difficulties that are inherent in almost any population estimate. From an inspection of Table 2, it is understood that fishermen were not fully sampling age-group III early in the summer because many fish of that age were illegal. However, the traps caught all of age-group III and older apparently without selection. Therefore, only estimates of age-group III based on trap-caught fish will be valid. Table 3 gives complete data on a Schnabel type estimate based on fish captured by traps only from June 2 until July 15. On June 16 and July 2, 3, and 5 the number marked and recaptured does not equal the number handled because 13 fish were removed from the traps on those days for other purposes. The marked fish at large on any one day are not always equal to the number of marked fish present in the lake on the previous day plus the number marked on that day. This discrepancy is caused by the fact that fishing was carried on concurrently, and the recaptures made by fishermen on certain days have been subtracted from the number at large. The population estimate is obtained by the formula given at the bottom of Table 3. The product AB has been divided by 100 so that the numbers do not become excessively large. The rounding which has been employed affects the estimate very little. The best estimate of the age-group III population is 435 based upon 143 recaptures. The high rate of recapture justifies considerable confidence in the estimate. DeLury's (1951) modification for calculating a more exact estimate by the Schnabel method gave 438. The limits of 95-percent confidence as calculated by DeLury's (1951) formula are 390–500. Totals are given for each 2-week period and the reader can estimate the population based on these values.

The data on recapture of the III-group redear sunfish by the traps indicates that the catch per unit effort of *unmarked* fish declined over the whole trapping period. In view of this trend an attempt can also be made to estimate the age-group III population by DeLury's method. There are several hinderances to the application of his method, however. Two traps were lost during the trapping period so that the effort expended, as measured by number of traps, is not constant from day to day. Also, the traps were run once on some days and twice on others. The regular schedule of examining the traps twice a day was interrupted occasionally by rain, high wind, or some other unforeseen circumstance. This means that effort expended in catching redears was not constant from day to day. However, it is possible to group the data in order to obtain units containing approximately equal effort, as DeLury suggests in his paper (see Table 4).

Effort has been measured by the number of traps lifted. If 8 traps are lifted twice in one day, effort is counted as 16 traps. An important objection to this method of measuring effort is that one trap, lifted twice a

TABLE 3.—*Data for the estimation of total number of age-group III redear sunfish by the Schnabel method*

[Fish were captured by cylindrical wire traps]

Date	Number handled (*A*)	Number marked	Number recaptured (*C*)	Marked fish at large (*B*)	$\frac{AB}{100}$
June 2	10	10	0	0	0.0
do. 3	27	27	0	10	2.7
do. 4	17	17	0	37	6.3
do. 5	7	7	0	54	3.8
do. 6	1	1	0	61	0.6
do. 7	5	5	0	62	3.1
do. 8	6	4	2	67	4.0
do. 9	15	14	1	71	10.7
do. 10	9	4	5	85	7.1
do. 11	18	13	5	89	16.0
do. 12	16	12	4	102	16.3
do. 13	5	3	2	112	5.6
do. 14	7	5	2	115	8.1
do. 15	19	16	3	119	22.6
Total	162	138	24	...	106.9
June 16	15	4	6	135	20.2
do. 17	20	14	6	139	27.8
do. 18	5	5	0	152	7.6
do. 19	15	13	2	156	10.4
do. 20	15	12	3	169	25.4
do. 21	8	4	4	181	14.5
do. 22	23	12	11	185	42.5
do. 23	11	5	6	197	21.6
do. 24	5	3	2	202	10.1
do. 25	3	1	2	205	6.2
do. 26	25	16	9	206	51.5
do. 27	4	2	2	222	8.9
do. 28	4	2	2	223	8.9
do. 29	7	4	3	224	15.7
do. 30	8	2	6	228	18.2
Total	168	99	64	...	289.5
July 1	6	0	6	230	13.8
do. 2	4	0	3	230	9.2
do. 3	9	0	4	230	20.7
do. 4	1	0	1	230	2.3
do. 5	7	0	5	229	16.0
do. 6	0	0	0	229	0.0
do. 7	14	7	7	229	32.0
do. 8	3	1	2	236	7.1
do. 9	10	6	4	237	23.7
do. 10	9	5	4	242	21.8
do. 11	8	2	6	247	19.8
do. 12	5	1	4	248	12.4
do. 13	7	3	4	249	17.4
do. 14	4	2	2	252	10.1
do. 15	7	4	3	254	17.8
Total	94	31	55	...	224.1
Grand Total	424	268	143	...	620.5

$$P = \frac{SAB}{SC} = \frac{62050}{143} = 435$$

day, may not catch twice as many fish as one trap, lifted once a day. Our data show that traps lifted twice a day yielded approximately twice as as many fish as traps lifted once a day. There were 172 traps, lifted once a day, which caught 190 fish, or 20.3 fish per trap. Traps lifted twice a day numbered 121 and caught 519 fish, or 42.8 fish per trap. With these data, at least, it does seem possible to measure effort by the number of traps lifted.

Table 4 illustrates the application of DeLury's method of analysis to the trap data. Accumulated catch for any one period is found by adding the number caught in the previous period to the accumulated catch up to that time. Catch per unit effort has been calculated by dividing the number of unmarked fish caught in the traps by the number of traps lifted. DeLury suggests that determination of the regression between these variables is usually the most practical way of handling the data. The results of the calculation of the regression are presented at the bottom of the table. The population was calculated by the formula:

$$Y - \bar{y} = b\ (X - \bar{x}),$$

where $Y = 0$, the population X can be computed as follows:

$$0.1702X = 96.38$$

$$X = 96.38/0.1702 = 566$$

TABLE 4.—*Grouped data for calculating the population of III-group redear sunfish by DeLury's method*

Date	Effort (traps lifted)	Catch of unmarked fish	Accumulated catch (X)	Catch per unit effort × 100 (Y)
June 2–3	32	37	0	116
do. 4–6	35	25	62	72
do. 7–9	28	23	87	82
do. 10–11	28	17	110	61
do. 12–14	35	20	127	57
do. 15–16	28	25	147	89
do. 17–19	35	32	172	91
do. 20–21	28	16	204	57
do. 22–23	28	17	220	61
do. 24–27	28	22	237	79
June 28–July 2	28	7	259	25
July 3–7	27	14	266	52
do. 8–11	24	14	280	58
do. 12–15	24	10	294	42

$SX = 2,465$ $SY = 933$

$\bar{x} = 176.1$ $\bar{y} = 66.4$

$Sx^2 = 105,676.9$ $Sy^2 = 7,225.2$

$Sxy = -17988.1$

Regression coefficient = −0.1702

Standard error of regression coefficient = 0.0737

Population = 566

The agreement between the Schnabel and DeLury estimates for III-group fish is not as good as might have been hoped; the DeLury estimate is 30 percent higher than the Schnabel estimate. Both estimates agree reason-

ably well, however, and it is reassuring to find that the DeLury estimate is only 66 fish above the upper 95-percent confidence limit placed on the Schnabel value. The age-group III population of redear sunfish can be estimated to be about 450–500 fish during the trapping period.

In addition to the estimates already described, population estimates of legal-sized redear sunfish of age-groups III, IV, and V+ have been made by the Petersen and Schnabel methods based on the fishermen's catch. These estimates are found in Table 5. The details of the calculations are

TABLE 5.—*Population estimates of redear sunfish in Gordy Lake, Indiana, 1950*

Type of estimate	Age group	Number of recaptures	Estimated number in group
Schnabel (traps)	III	143	435
DeLury		...	566
Petersen (fishermen)		11	288
Schnabel (traps)	III	65	165
Schnabel (fishermen)	(all legal-sized[1])	19	243
DeLury		...	288
Petersen (fishermen)		27	306
Schnabel (traps)	IV	178	238
Schnabel (fishermen)		40	316
DeLury		...	263
Petersen (fishermen)		6	68
Schnabel (traps)	V+	30	66
Schnabel (fishermen)		12	61
DeLury		...	89

[1] 5 inches, total length, or longer

not given because of space limitations. The methods outlined above have been followed except in one instance. The trap data showed that the older redears moved out of shallow water during the month of July which change of habitat led to a lowered catchability during that time. Therefore, the trap data from June 2 to June 29 were used for the DeLury estimates of fish older than age III.

Results from the four independent methods used to estimate the population of legal age III, age IV, and age V+ redears are in exceptionally good agreement. It can be said confidently that the legal-sized III-group number about 250 fish (about half the total of age-group III). There were approximately 280 IV-group and about 70 fish in the V+ group. It will be shown later that the V-group fish were practically absent from the population and this accounts for the small number of older fish in the population.

Population Estimates of Bluegills

The bluegill has consistently been the most abundant fish among the sport species studied in Indiana lakes. Gordy Lake is no exception. It has already been shown that bluegills were by far more numerous in the

fishermen's catch than the other species. The information to follow shows that the bluegill was about 13 times more numerous than the next most abundant fish, the redear sunfish. This figure agrees almost precisely with the relative numbers of these species in the creel census.

The length-frequency diagram of the bluegills caught by fishermen in successive two-week periods from June 2 to September 4 (Fig. 1) is also designed to show the role of the various age groups in the catch. The length frequency of III- and IV-group fish which were aged by the scale method are distinctively shown. Advancing the age boundaries by 5 mm. each half-month keeps pace fairly accurately with bluegill growth. The boundaries have been extrapolated back to the beginning of fishing for the population estimates of the various ages. Age-groups III and IV overlap so widely that it is impossible to separate these age groups for analysis. The same is true for age-groups V, VI, and VII although they are not shown on the figure. The two modal points in the length-frequency in the first period is an interesting feature of the figure. Without age analysis, it would be easy to fall into error by regarding them as representing two age groups. By following the first and highest mode through the summer, we find that it disappears and another takes its place. The original peak is satisfactorily shown to be a complex made up of both III- and IV-group fish. The new peak which enters the distribution later in the summer is due to the recruitment of III-group fish into the legal population. A comparison of the modal points for age-groups III and IV in Figure 1 with Hile's (1931) sketchy information on the age and growth of Gordy Lake bluegills shows that the fish were about 10 mm. larger at each of these ages in 1929 than in 1950. Hile's fish were sampled by gill nets and his data show that fish older than age III were relatively more plentiful in the 1929 than in the 1950 samples. It is possible that he sampled the faster growing members of the age III group.

The same procedures were used in making population estimates for bluegills as were described for redear sunfish. It was not possible to use DeLury's method because the traps did not capture bluegills efficiently.

Results of the more reliable of the population estimates (Table 6) indi-

TABLE 6.—*Population estimates of bluegills in Gordy Lake, Indiana, 1950*
[All estimates based on recaptures by fishermen]

Type of estimate	Age group	Number of recaptures	Estimated number in group
Petersen	II and III	34	5690
Schnabel	(below legal size)	42	5348
Petersen	III and IV	92	6897
Schnabel	(all legal-sized[1])	141	6331
Petersen	V, VI, and VII	12	1259
Schnabel		23	1345

[1] 5 inches, total length, or longer

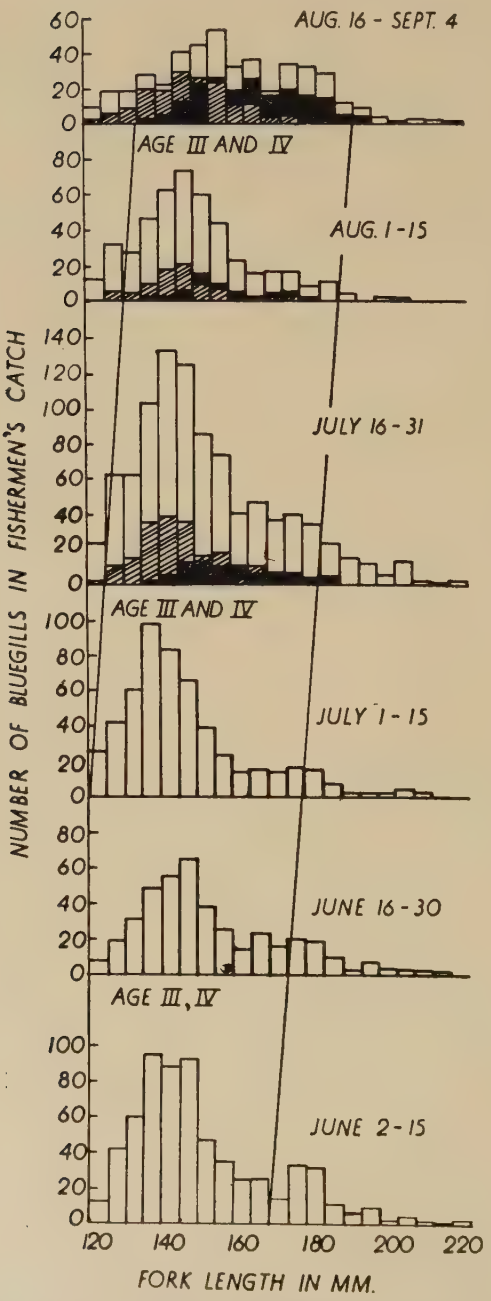

FIGURE 1.—Length-frequency distribution of bluegills in the fishermen's catch in Gordy Lake, Indiana, 1950. Frequencies are given for 2-week intervals. The III-group fish whose scales were examined are represented by bars with diagonal lines. The IV-group fish whose scales were examined are represented by blackened bars. The arbitrary length boundaries separating age III and age IV from older fish is shown to increase 5 millimeters each half-monthly period.

cate a remarkably good agreement between comparable estimates. For unknown reasons, no good Schnabel type estimates could be made from the trap data. Among the fish which were illegal as of early June, only 4 recaptures were made during the trapping period; 8 recaptures of legal-sized III- and IV-group fish were made during the trapping period; 2 recaptures were obtained for the older age groups. None of the Schnabel estimates based on such small numbers of recaptures were considered as reliable as the ones presented in the table. These estimates were all considerably higher than those given and had the wide range of error to be associated with the small number of recaptures.

The estimates lead to the conclusion that there were about 6,600 legal III- and IV-group bluegills in Gordy Lake. About half the undersized II- and III-group fish were 3 years old; a total of about 6,600 + 2,625 = 9,225 fish of the two ages were present. Age-groups V, VI, and VII have been lumped together and provide a population of about 1,300 fish. The total population of legal-sized bluegills was about 7,900.

Population Estimates of Other Species

Warmouth, green sunfish, and pumpkinseeds were caught only incidently by the anglers who fished mainly for bluegills and redear sunfish. The fishing record previously presented shows a low catch of these species, and for this reason the fisherman's catch cannot be used for population estimates. A Schnabel estimate based on trap-caught fish seems to be the best opportunity to acquire information about the numbers of these minor panfish. Because these species entered the traps in small numbers, all ages and sizes were combined. The population estimates are found in Table 7. The percentage of the trap-caught fish which were legal-sized is

Table 7.—*Population estimates of warmouth, green sunfish, and pumpkinseeds*
[All estimates were made by the Schnabel method and were based on trap-caught fish. All sizes and ages were combined]

Species	Number of recaptures	Estimated number in population	Percentage legal	Estimated legal-sized fish in population
Warmouth	3	583	59	344
Green sunfish	7	295	69	204
Pumpkinseed	14	162	14	23

given in order to permit some judgment as to the relative size of the fish making up the population. Because so few fish of these species were marked or recaptured, uncertainty in the estimates results. However, on the basis of the information obtained, it may be held certain that these species were present in smaller numbers than either bluegills or redear sunfish. A smaller percentage of the minor panfish were of legal size, particularly the pumkinseed of which only 14 percent of those trapped were legal.

Again, our studies have failed to provide a reliable estimate of the large-

mouth bass population. A special effort was made to obtain them for marking but only 20, of which 12 were legal (10 inches total length, 243 millimeters fork length), were marked. A Schnabel estimate based on bass caught by fishermen yielded the figure of $469/4 = 117$ legal fish of all ages in the lake. A Petersen estimate based on marked legal bass at large as of July 15 was $9 \times 31/1 = 279$. Probably the population of legal-length bass did not exceed 300 and may have been as low as 100.

Population estimates were not possible for other species previously mentioned.

Standing Crop

From a knowledge of the approximate size of the populations of various species and their average weight, it was possible to estimate the standing crop of the larger fish of each species in Gordy Lake (Table 8). Bluegills contributed by far the most weight among the species whose abundance was estimated. Redear sunfish and largemouth bass occupied a secondary position with warmouth, green sunfish, and pumpkinseeds following

Table 8.—*Estimate of standing crop of legal-sized fish of six species in Gordy Lake, Indiana*

Species	Number of legal-sized[1] fish in population	Average weight (pounds)	Total weight (pounds)	Standing crop (pounds per acre)
Bluegill	7,900	0.167	1320	46.3
Redear sunfish	600	0.175	105	3.7
Warmouth	340	0.125	42.5	1.5
Pumpkinseed	25	0.117	0.3	[2]0.1
Green sunfish	200	0.197	19.4	0.7
Largemouth bass	117–280	0.889	104–249	3.7–8.7

[1] Minimum legal total length—10 inches for bass and 5 inches for other species
[2] Less than 0.05

in that order. The standing crop of legal-sized fish of these species was about 56 or 61 pounds per acre, depending upon which population estimate for largemouth bass is accepted. Bluegills made up 79 percent of the total estimated standing crop. It has been indicated that the species, whose abundance could not be estimated, occurred in relatively small numbers as judged by their frequency in the fishermen's catch. Probably the total standing crop of all fish was no more than 20 pounds per acre more than that given above, or about 78 pounds per acre. This value corresponds very well with the amount to be expected on the basis of Rounsefell's (1946) summary of standing crop statistics. It will also be noticed that the yield (25.4 pounds per acre) also corresponds very well with Rounsefell's predicted value.

Estimate of Mortality Rates

The author has chosen to express the various mortality rates by using the terms: total annual mortality rate, rate of exploitation, and expectation

of natural death. These terms were selected because they are derived directly from the original data and because they are concepts which are commonly met. The percentage rate of exploitation and the expectation of natural death are an allocation of the total annual mortality rate to the two sources of death and should not be confused with annual mortality rates from fishing and from natural causes both of which would be higher than the percentages given here (see Ricker 1948, p. 4, for definitions and statements of relationships).

The total annual mortality rate can be estimated from the relative frequency of each age in the catch. Age determinations, by the scale method, of fish caught by fishermen form the basis for the estimates of total mortality. Scales were collected from every fish in alternate weeks from July 15 to September 4.

The determination of the rate of exploitation was complicated by the fact that fishing was being done at the same time marking was in progress, and also by the fact that the marking was continued for 1½ months. The most practical solution to these problems is to use a Schnabel type method for determining rate of exploitation as given by Ricker (1948, p. 50, formula 14). This procedure involves tabulation of the number of fish marked to date, uncorrected for known deaths from fishing. Computation of the rate of exploitation by this method is subject to the same conditions as any Schnabel type estimate. The most probable errors associated with this method and the effects of these errors on the resulting estimates are the same as discussed previously in connection with population estimates (page 51). Under the circumstances it seems to be the best approximation that can be made on Gordy Lake fish.

Bluegills.—The 972 scale samples taken for age determination consisted of 50.3 percent of all bluegills caught after July 15. The age distribution as determined from the scales of these fish was as follows: age-group II, 9; age-group III, 446; age-group IV, 352; age-group V, 58; age-group VI, 16; age-group VII, 4; age-group VIII, 1. These figures can be combined to form a "catch curve" (Ricker, 1948) and total mortality can be calculated from the slope of the curve beyond the point at which all fish are vulnerable to fishing. Total mortality can also be determined by the Jackson (1939) method as is done here. Age-group II fish are obviously not completely vulnerable to fishing. This view is supported both by the frequency of the II-group in the catch and by the data of Figure 1. The III-group fish were mostly of legal size but again not all of them had attained the legal length limit at the time scale samples were taken (see Fig. 1). Therefore, the estimate of total annual mortality must be based on fish of age-group IV and older. By the Jackson method the total annual survival thus becomes:

$$\text{Total annual percentage survival} = \frac{1 + 4 + 16 + 58}{4 + 16 + 58 + 352} \times 100 = 18.4;$$

$$\text{Total annual percentage mortality} = 100.0 - 18.4 = 81.6.$$

A part of this total annual mortality is due to exploitation. The Schnabel type estimate of the percentage rate of exploitation as explained above is

342,707/1,062,591 × 100 = 32.2 percent for all age groups. Since this rate of exploitation applies only to summer fishing, some indication of the yearly rate is desirable. The owner of the lake indicated that winter fishing was very light on Gordy Lake. It is estimated that fishing in late fall and winter would raise the yearly percentage exploitation rate about 3 above the summer rate, or to 35 percent. The yearly expectation of natural death (percentage basis) becomes: total annual mortality rate minus rate of exploitation, or 82 − 35 = 47 percent. An annual expectation of natural death of 47 percent is within the same magnitude as those estimated for bluegills in other Indiana lakes by Ricker (1945b).

Redear sunfish.—Scale samples were taken from 60 percent of the 173 redear sunfish caught after July 15. The age distribution of the 104 fish was as follows: age-group II, 10; age-group III, 61; age-group IV, 25; age-group V, 1; and age-group VI, 7. The almost complete absence of age-group V in the catch indicates a population with variable recruitment. Under these conditions, it is difficult to put a great deal of confidence in a value for total annual mortality based on these figures. However, some indication of the average survival of these fish, during the years represented by the samples, may give some indication of the order of magnitude that future investigations may reveal. Neither age-group II nor age-group III was completely vulnerable to fishing although III-group was nearly so (see Table 2). Total annual survival is computed by the Jackson method as follows:

$$\text{Total annual percentage survival} = \frac{7 + 1}{1 + 25} \times 100 = 30.8;$$

Total annual percentage mortality = 100.0 − 30.8 = 69.2.

When III-group fish are included in the sample the estimated total mortality becomes 62 percent. The average rate probably lies within the range of 60 to 70 percent.

The summer rate of exploitation as estimated by a Schnabel type calculation is 5,255/19,800 × 100 = 26.0 percent for all age groups. The yearly rate of exploitation would be about 29 percent including the late fall, winter, and early spring fishing. The yearly expectation of natural death then becomes: 69 = 29 = 40 percent.

Ricker (1945a) estimated mortality rates of redear sunfish. His data showed the same evidence of variable recruitment as ours did. He also concluded from his data that redears have a greater survival rate than bluegills. This conclusion is verified by the findings presented here.

Largemouth bass.—The mortality estimates for largemouth bass are based on very little information. It has been difficult to get adequate samples of this species because they are not usually caught by our trapping methods and also because they are apparently not very numerous in the Indiana lakes which have been studied. The largemouth bass is important, nevertheless, in the sport fishing of the country, and the data will be presented even though they are admittedly insufficient.

The age determinations for the 17 bass from which scales were taken were as follows: age-group III, 6; age-group IV, 7; age-group V, 3; age-group VIII, 1. No fish were sampled in the age-groups VI or VII. The estimated survival is as follows:

$$\text{Total annual percentage survival} = \frac{1+0+0+3}{0+0+3+7} \times 100 = 40.$$

$$\text{Total annual percentage mortality} = 100 - 40 = 60.$$

The rate of exploitation is estimated as $220/616 \times 100 = 35.7$ percent. This rate of exploitation is much greater than has been recorded before for largemouth bass in Indiana. Ricker (1945a) calculated an exploitation rate of 12 percent for Shoe Lake and Gerking (1950) reported 17 percent for Oliver Lake. Gordy Lake is known to local residents as a good bass fishing lake which fact possibly may indicate that our determination is at least approximately correct. Since, according to the owner of the lake, practically no bass are caught in winter, the above value will be taken as the yearly rate of exploitation. The expectation of natural death is $60 - 36 = 24$ percent.

Other species.—The limited number of warmouth, pumpkinseeds, and other species in the catch does not allow an estimation of total annual mortality rates. Some information about rate of exploitation is available for green sunfish and pumpkinseeds. Although 61 warmouth were marked, no marked fish were found in the fishermen's catch of 14. The rate of exploitation is therefore not known but must be very low. A Schnabel estimate of the rate of exploitation of green sunfish is $19/860 \times 100 = 2.2$ percent and the same value for pumpkinseeds is $205/1857 \times 100 = 11.0$ percent. These exploitation rates are low, as would be expected because these species are not as desirable to the fishermen.

Appraisal of the Gordy Lake Fishery

Gordy Lake is about average with regard to fishing success, yield, and fish productivity among the Indiana lakes studied and also in comparison with Rounsefell's summary. Pressure of cane-pole fishing (2,538 pole-hours), the principal method of angling in Indiana waters, was somewhat below the average for six lakes investigated previously (3,211 pole-hours; see Gerking, 1950), but the catch per unit effort (15.2 fish or 2.72 pounds per 10 pole-hours) was above average for the other Indiana lakes. The six estimates of the standing crop of bluegills that have been made on three Indiana lakes up to this time varied from 1 to 102 pounds per acre. Gordy Lake, with 46 pounds of bluegills per acre, stands about midway in the range. It has already been noted that this standing crop is close to what would be expected from Rounsefell's calculations.

The rates of exploitation of 29 percent for redear sunfish and 35 percent for bluegills are approaching the highest rates ever measured in our lakes. This heavy exploitation undoubtedly is in part a reflection of the increased fishing pressure which has occurred throughout the country since World

War II. Still these rates are not dangerously high. Neither is as great as the expectation of natural death. The data on largemouth bass revealed that the rate of exploitation was 36 percent whereas the expectation of natural death was only 24 percent. This relatively high rate of capture may cause some concern. Although these measurements were based on admittedly insufficient data, they do indicate that this species deserves much more intensive study.

Indiana has had a year-round season on panfish since 1948 as a result of studies similar to this one. There is no cause to believe that this practice has resulted in a decline of the fishery in Gordy Lake. Furthermore, continuation of the year-round season would seem to be justifiable on the basis of the information presented here. Although Gordy Lake is undoubtedly not the most heavily fished natural lake in Indiana, it is well known locally and was visited by many people from various other parts of the state. As nearly as can be judged by the available information, Gordy Lake represents about the average condition to be expected on lakes of its type.

One of the most satisfying parts of the investigation lies in the population estimates. This is the first time that DeLury's type of population estimate has been tested against the other, more widely used measures. The agreement between the different methods was good. The usefulness of DeLury's estimate was limited in our experiment for the reason that it depends largely upon a high rate of capture of the population. The trapping method used by us was efficient for redear sunfish but not for other species. Omand (1951) was also able to measure the population of a minor species by DeLury's method. Sport fishing was not efficient enough to permit the use of DeLury's method to estimate the abundance of any species. The Petersen and Schnabel estimates do not rely on such efficient capture and hence are more useful under ordinary circumstances. It seems firmly established that the abundance of the more common fish in relatively large bodies of water can be successfully measured if the study is planned carefully and sufficient effort is exerted in collecting the data. One of the most serious deficiencies in the methods used here lay in the fact that the population characteristics of all important species could not be determined. In the future more effort should be expended in securing as much information as possible about these fishes in order more nearly to complete the picture of the fish and fishing in a lake.

The collection and analysis of information such as this is laborious and time-consuming. Yet an accumulation and synthesis of such information should yield valuable data regarding important fishery problems. Correct understanding of the relationships between fishing effort and rate of exploitation, between yield and rate of exploitation, between catch per unit effort and rate of exploitation, between catch per unit effort and standing crop, and other important considerations all wait extensive and accurate measurements.

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Literature Cited

DeLury, D. B.
1947. On the estimation of biological populations. Biometrics, Vol. 3, pp. 145–167.
1951. On the planning of experiments for the estimation of fish populations. Jour. Fish. Res. Bd. Can., Vol. 8, pp. 281–307.

Gerking, Shelby D.
1950. Populations and exploitation of fishes in a marl lake. Invest. Ind. Lakes and Streams, Vol. 3, No. 11, pp. 389–434.

Hile, Ralph
1931. The rate of growth of fishes of Indiana. Invest. Ind. Lakes, Vol. 1, No. 2, pp. 7–55.

Jackson, C. H. N.
1939. The analysis of an animal population. Journ. Animal Ecol., Vol. 8, pp. 238–246.

Kirsch, P. H.
1895. Report upon explorations made in the Eel River basin in the northeastern part of Indiana in the summer of 1892. Bull. U. S. Fish Comm., Vol. 14, pp. 31–41.

Omand, D. H.
1951. A study of populations of fish based on catch-effort statistics. Journ. Wildlife Man., Vol. 15, pp. 88–98.

Petersen, C. G. J.
1896. The yearly immigration of young plaice into the Limfjord from the German Sea, etc. Rep. Dan. Biol. Sta., Vol. 6, pp. 1–48.

Ricker, W. E.
1942. Creel census, population estimates and rate of exploitation of game fish in Shoe Lake, Indiana. Invest. Ind. Lakes and Streams, Vol. 2, No. 12, pp. 215–253.
1945a. Abundance, exploitation and mortality of the fishes in two lakes. Invest. Ind. Lakes and Streams, Vol. 2, No. 17, pp. 345–448.
1945b. Natural mortality among Indiana bluegill sunfish. Ecology, Vol. 26, pp. 111–121.
1948. Methods of estimating vital statistics of fish populations. Indiana Univ. Publ., Sci. Ser., No. 15, 101 pp.

Rounsefell, George A.
1946. Fish production in lakes as a guide for estimating production in proposed reservoirs. Copea, 1946, No. 1, pp. 29–40.

Schaefer, Milner B.
1951. Estimation of size of animal populations by marking experiments. Fish. Bull., U. S. Fish and Wildlife Serv., Vol. 52, pp. 191–203.

Schnabel, Zoe E.
1938. The estimation of the total fish population in a lake. Am. Math. Monthly Vol. 45, pp. 348–352.

THE MOVEMENT OF TAGGED LAKE TROUT IN LAKE SUPERIOR, 1950–1952

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Abstract

A total of 733 native lake trout was tagged at two widely separated localities in Lake Superior; subsequent recaptures numbered 155 fish (21.1 percent) during the year following marking. In October 1950, 116 large lake trout (average total length, 27.3 inches) were tagged near Keweenaw Point, Michigan. Fifteen (12.9 percent) were recovered during the first year at points as far west as the Gooseberry River, Minnesota (190 miles), north to the Slate Islands, Ontario (95 miles), and east to Grand Marais, Michigan (100 miles). Nine fish (7.8 percent) were recovered during the second year after marking. Returns from 617 tagged lake trout of smaller size (average length, 18.2 inches) released in the Apostle Island region of Wisconsin during the period June 12 to August 6, 1951, numbered 140 (22.7 percent) during the first year. Of these fish, 90 percent were recaptured within a radius of 50 miles of the points of release. Seventy-six percent were caught in Wisconsin, 14 percent in Minnesota, and 9 percent in Michigan waters. The fish retaken in Michigan had moved 120 to 255 miles between the time of release and recapture, traveling as far east as Grand Marais. Lake trout recaptured at distances of more than 50 miles from the tagging locality were of larger average size than marked fish caught within this radius.

The four types of tags used in the marking of lake trout in the Apostle Island region, together with the number tagged and percentage recovered during the first year were as follows: 103 aluminum lower-jaw tags (used only on fish less than 17 inches in length when marked)—10.7 percent; 200 monel upper-jaw tags —14.0 percent; 162 streamer tags—19.8 percent; and 152 Peterson tags—45.4 percent. Obviously lake trout marked with the Petersen tag, with the discs and ends of the pin projecting from each side near the point of maximum girth, were more vulnerable to the fishery than were fish marked with other tags. The recoveries of marked fish show that Lake Superior lake trout—particularly fish of large size—may move many miles and freely cross political boundaries; and that the rate of harvest is moderately high for a fish with a life history as long as that of the lake trout.

Introduction

A total of 733 lake trout (*Salvelinus namaycush*) was tagged at two localities in Lake Superior. In October 1950, 116 lake trout, mostly sexually mature fish of large size (average length 27.3 inches; range 18.2 to 34.6) were tagged on the upper jaw with No. 3 monel strap tags by U. S. Fish and Wildlife Service employees and released off Keweenaw Point, Michigan. During the period July 31 to August 6, 1951, 514 lake trout averaging 18.5 inches (range, 9.7 to 32.6) were tagged by the Service in the Apostle Island Region of western Lake Superior. Two hundred were marked on the upper jaw with strap tags; 152 were marked with Petersen tags just anterior to the dorsal fin; and 162 were tagged in this same body area with the Atkins or streamer tag (Rounsefell and Kask, 1945), applied as suggested by Joeris (1953). Also in the Apostle Island region, during the period June 12 to August 2, 1952, personnel of the Wisconsin Conservation Department marked 103 lake trout of illegal size (*i.e.* under 17 inches, total length) with aluminum strap tags which encircled the lower jaw.

All lake trout tagged were taken from pound nets. Legal-sized fish were either caught in nets rented from a commercial fisherman (Keweenaw Point) or purchased at the market price prevailing at the time of marking (Apostle Islands). The fish were anesthetized with urethane, measured, tagged, and released alongside the net in which they were caught.

Immediately after completion of the marking of lake trout near the Apostle Islands in 1951 the work was publicized by several newspapers in the vicinity, some fishermen were informed personally, and all licensed commercial operators fishing United States waters of Lake Superior were contacted by letter. In Ontario, field officers and some commercial fishermen were informed of the work by the Ontario Department of Lands and Forests. Rewards were not offered for the return of tags.

In addition to the cooperation received from many fishermen who reported recoveries of marked fish, valued assistance was given in this study by Ben Gustafson, of the Minnesota Department of Conservation, who forwarded many of the tag returns received from Minnesota fishermen; by Clifford Tetzloff and Joseph Beil, who assisted in the field work; by George Lunger, who assisted in the analysis of the data; by Ralph Hile, who read the manuscript and offered suggestions; and by Vito J. Cangemi, who prepared the illustrations.

Movement of Tagged Lake Trout

Keweenaw Point.—Localities of recovery of lake trout marked in Bete Grise Bay, near Keweenaw Point, during the spawning season in October 1950 are shown in Figure 1. Three fish were recovered at widely separated points within 19 to 23 days after release. One lake trout, which had moved at an average rate of at least 10 miles per day after being tagged, was retaken off the Gooseberry River, Minnesota, 190 miles from Ke-

weenaw Point; another was caught near the Slate Islands, Ontario, 95 miles to the north; and the third was recaptured off the port of Munising, Michigan, 73 miles southeast of the locality of release. These were the only recoveries during the first month after tagging, but a later recapture extended the eastward limits of recoveries to a point off Grand Marais, Michigan, 100 miles from Keweenaw Point. In contrast, seven recoveries, scattered through the months of December to September, were made within 35 miles of the tagging locality.

In October 1951, one year after tagging, three lake trout were recovered within an 8-day interval and within a 2-mile radius, about 60 miles from the tagging locality, on the west-central shore of the Keweenaw Peninsula (see Fig. 1). The recapture of these fish together at this locality as the spawning season neared is most interesting in the light of returns during the second year after tagging. After three widely scattered recoveries during the spring and summer of 1952 (one in local waters; one from Grand Marais, Minnesota, 135 miles away; and one near the Apostle Islands, 150 miles from Keweenaw Point) one lake trout was recaptured on September 10 and five during the period October 3–9 within a radius of about 20 miles from the tagging locality. No marked fish were recovered during September or October of either year in waters not adjoining the Keweenaw Peninsula.[1] Lake trout recovered locally (*i.e.* within 35 miles from the place of release) during months other than September or October averaged 23.9 inches in total length; the mean length of fish recaptured at distant points, or in local waters as the spawning season approached, was 27.5 inches. Although the data are admittedly not extensive, the general pattern of recoveries permits the conjecture that the larger sexually mature lake trout tagged off Keweenaw Point in October 1950 tended to disperse widely through the lake after the spawning season and that some (perhaps many or most) returned to the general vicinity of tagging during subsequent spawning seasons.

Apostle Islands.—Most of the 617 lake trout tagged in western Lake Superior were released along a 20-mile section of shoreline extending westward from Sand Island (Fig. 2). Many were recaptured in local waters in the relatively intensive lake trout fishery conducted throughout the Apostle Island region and westward. Ninety percent of the recoveries (126 fish) were made within 50 miles of the tagging locality (36 percent within 10 miles). A total of 76.4 percent was recaptured in Wisconsin, 14.3 percent in Minnesota, and 9.3 percent in Michigan waters of Lake Superior. The marked fish caught in Michigan had traveled more than 100 miles between the time of release and recapture. Six had moved to various points along the Keweenaw peninsula, 4 to Marquette, 2 to Munising, and 1 to a point 23 miles north of Grand Marais. The last three fish had traveled about an equal minimum distance—255 miles—between their respective times of release and recovery.

[1] The recapture of a 28.3-inch tagged lake trout on September 25, 1952, off the Apostle Islands, 140 miles from the tagging locality, was reported after this paper had been submitted to the printer.

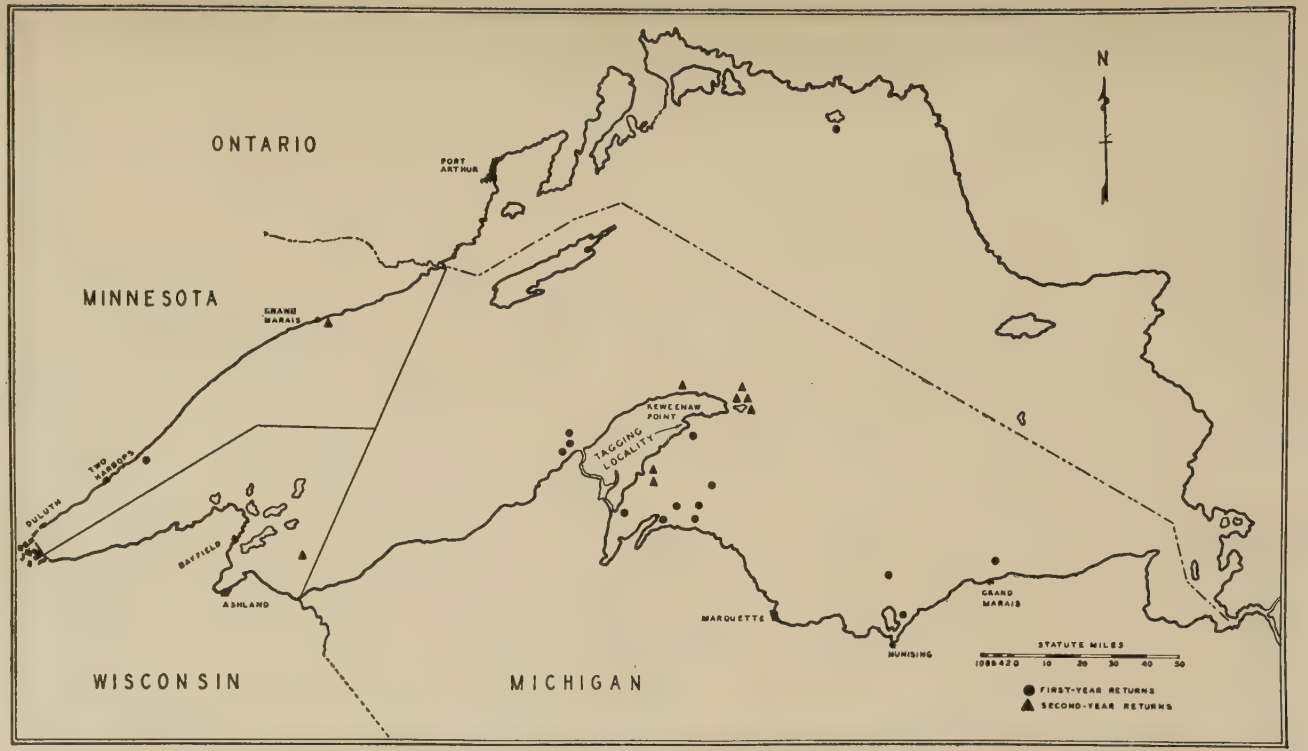

FIGURE 1.—Localities of recovery of lake trout tagged near Keweenaw Point, October 11–27, 1950.

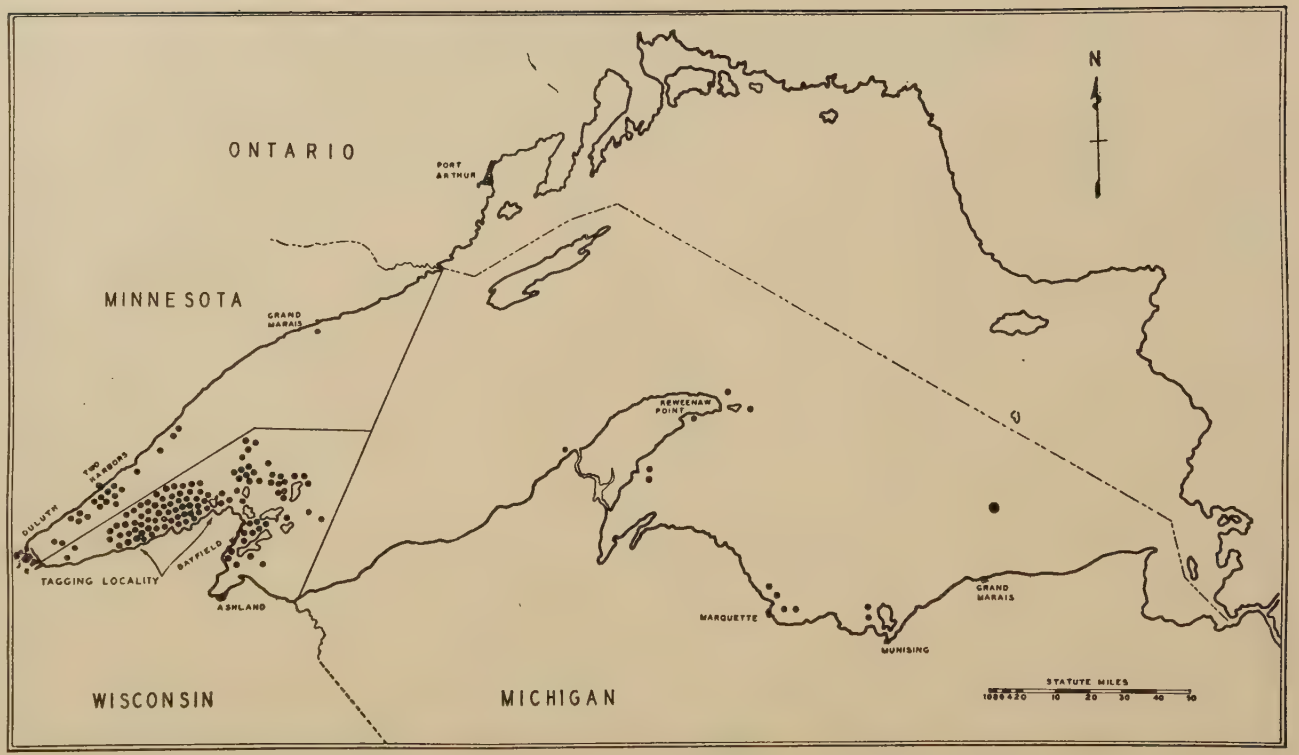

FIGURE 2.—Localities of recovery of lake trout tagged in the Apostle Island region, June 12-August 6, 1951.

Lake trout moving the longer distances tended to be the larger ($X^2 = 14.370$; $p < 0.001$). The average length at the time of marking of fish which were recovered within 50 miles of the tagging locality was 18.4 inches, whereas the mean length of those moving greater distances was 21.2 inches (a difference of 2.8 inches). The relationship between length and the distance traveled before recapture during the first year after marking, is further shown in Table 1. No fish of the 9.0- to 15.9-inch length group was recovered more than 50 miles from the place of release, whereas 4.8 percent of the recoveries in the 16.0- to 19.9-inch class and 27.8 percent of those 20.0 or more inches in length had traveled beyond a 50-mile radius.

TABLE 1.—*Relationship between size of lake trout tagged in the Apostle Island region of Lake Superior and distance traveled before recapture, 1951-52*

Total length (inches)	Distance traveled (miles)			
	Less than 50		More than 50	
	Number	Percentage	Number	Percentage
9.0–15.9	21	100.0	0	0.0
16.0–19.9	79	95.2	4	4.8
20.0–30.9	26	72.2	10	27.8

Although some correlation was evident between the period of liberty of tagged lake trout in the Apostle Island region and distance traveled, the relationship was not strong ($r = 0.257$; $p < 0.01$) and, as was shown above, many fish did not travel far, even after several months of freedom. Of all returns in each quarterly period during the year two-thirds or more were within 30 miles from the place of release. The average distance traveled for all fish recovered was 35.4 miles.

Returns to date give little indication of the location of spawning grounds of the relatively few sexually mature lake trout marked in the Apostle Island region. No recoveries were reported during October or early November (generally conceded to include the spawning season for lake trout in Lake Superior). Nineteen of 23 lake trout recaptured during September (when some lake trout apparently begin to move toward the spawning grounds in some areas) were almost certainly sexually immature fish (average length, 17.1 inches; range, 10.4 to 20.2). Two fish caught in early September which may have been mature (23.3 and 30.0 inches in length when tagged) were taken within 5 miles of the place of release; a 27.5-inch fish was taken off Marquette, 235 miles away, on September 13; and one lake trout 23.4 inches long was caught off Minnesota's North Shore, 25 miles from the tagging locality, on September 29.

Other workers also have shown that Great Lakes lake trout are extensive travelers and ignore political boundaries. Smith (1933) reported the recovery of seven lake trout in Lake Michigan which had moved more than 50 miles, including one which had traveled about 135 miles. Schneberger

(1936) wrote that one tagged lake trout had moved approximately 90 miles between release and recapture. Smith and Van Oosten (1940) analyzed the data on 218 recoveries from 1,416 small lake trout (average length, 12.8 inches) tagged and released near Port Washington, Wisconsin, in 1929–1931.[2] They reported the recapture of 16 marked lake trout which, after periods of liberty of 16 months to about 7 years had moved 100 to 225 miles. However, 77.6 percent of the recoveries were made within 50 miles of the tagging locality. One lake trout released off the port of Munising in Lake Superior in 1941 by the State of Michigan was recovered in 1949 in Minnesota waters, about 300 miles away (unpublished).

In contrast to the above records of extensive movement, Fry (1953) found that the lake trout population in South Bay, Lake Huron, appeared to be confined essentially to that body of water. Of about 3700 lake trout tagged in South Bay in the years 1949–1951, only 3 were recovered in outside waters.

Rate of Recovery of Tagged Lake Trout

Percentage recovery from the different groups tagged.—Fifteen lake trout (12.9 percent) were recovered during the first year from the 116 marked fish released off Keweenaw Point in October 1950. During the second year after marking 9 additional fish (7.8 percent) were retaken; thus 20.7 percent were recaptured during the 2-year period. Returns were made at a faster rate for fish marked in the Apostle Island region in 1951, where 140 (22.7 percent) of the 617 lake trout tagged were recaptured during the first year after release. Thirty-one percent of the returns were made within a month after tagging, and 46 percent within 2 months. From this point, recoveries tended to follow the trend of activity in the commercial fishery; only scattered returns were obtained during the winter months when fishing is light, whereas 36 percent of the total recaptures occurred during April, May, and June 1952 after intensive fishing had been resumed. Only 5 of the 164 recoveries of fish released off Keweenaw Point and in the Apostle Island region were caught by sport fishermen as compared with 159 taken by commercial operators.

Smith and Van Oosten (1940) obtained a 15.4-percent recovery during an 8-year period from 1,416 lake trout tagged in Lake Michigan in 1929–1931.

The length-frequency distributions of lake trout tagged and of marked fish recovered are given in Table 2. The data for Keweenaw Point include all recoveries prior to the second anniversary of the tagging date, but data for the Apostle Island region concern only fish recaptured during the first year. Rate of return was lower for fish less than 17 inches in length than for legal-sized fish ($X^2 = 6.472$; $p < 0.02$). However, among legal fish there is no evidence that recovery rate was influenced by size.

Fishermen supplied 63 total-length measurements of lake trout which had been tagged in the Apostle Island region and recovered after varying

[2] Data from earlier (1933) work by Smith were included in this study.

intervals of freedom. Although differences in rate of growth related to length of fish [3] or type of tag were not demonstrable, there was some difference in growth related to time out. Seven fish measured within 4 months after tagging had increased an average of 0.8 inch in length; 13 caught within the next 4 months had grown 0.9 inch; 21 caught during the ninth and tenth month after release had an increment of 2.1 inches; and 22 lake trout which were free for more than 10 months had grown 2.7 inches.

TABLE 2.—*Length-frequency distributions of lake trout tagged and of those recovered in Lake Superior, 1950-52*

Total length (inches)	Locality where tagged					
	Keweenaw Point, 1950			Apostle Islands, 1951		
	Number tagged	Recoveries[1]		Number tagged	Recoveries[2]	
		Number	Percentage		Number	Percentage
9.0–10.9	..	...	....	4	2	50.0
11.0–12.9	..	...	....	13	1	7.7
13.0–14.9	..	...	....	64	7	10.9
15.0–16.9	..	...	....	161	35	21.7
17.0–18.9	1	0	0.0	128	37	28.9
19.0–20.9	9	2	22.2	113	29	25.7
21.0–22.9	5	2	40.0	56	15	26.8
23.0–24.9	7	4	57.1	12	5	41.7
25.0–26.9	21	2	9.5	8	2	25.0
27.0–28.9	36	9	25.0	12	3	25.0
29.0–30.9	21	2	9.5	6	3	50.0
31.0–32.9	13	3	23.1	4	0	0.0
33.0–34.9	2	0	0.0	...	..	....
Incomplete data	1	0	0.0	[3]36	1	2.8

[1] Includes all recoveries during the 2 years after tagging
[2] Includes recoveries during only the first year after tagging
[3] Fish of illegal size which were not measured when tagged

Comparison of rates of return from different types of tags.—Recoveries of lake trout tagged in the Apostle Island region are tabulated according to type of tag and size of fish (illegal or legal at a size limit of 17 inches, total length) in Table 3.

Aluminum jaw tags, used only on fish of illegal size, showed a return of 10.7 percent.

Monel strap tags were returned at a rate of 8.0 percent from illegal fish and of 16.0 percent from fish of legal size. The latter figure is somewhat higher than the 12.9-percent recovery from large lake trout tagged off Keweenaw Point with the same type of tag. For lake trout of all sizes combined the recapture rate was 14.0 percent.

A total of 15.3 percent of the streamer tags placed on illegal fish and 24.7 percent of those on larger fish was recovered. The significant difference in the rate of return between jaw and streamer tags may have been due largely to the comparative inconspicuousness of jaw tags. Also, the presence of the streamer tag may have increased the vulnerability of the fish to gill nets.

[3] Eighty-four percent of the recaptured lake trout which were measured were in the 14.0- to 22.0-inch length group.

TABLE 3.—*Recoveries during the first year of lake trout tagged in the Apostle Island region of Lake Superior, 1951*

Type of tag	Total length (inches)								
	9.7–16.9			17.0–32.6			9.7–32.6		
	Number tagged	Recoveries		Number tagged	Recoveries		Number tagged	Recoveries	
		Number	Percentage		Number	Percentage		Number	Percentage
Aluminum jaw	103	11	10.7	...	..	....	103	11	10.7
Monel jaw	50	4	8.0	150	24	16.0	200	28	14.0
Streamer	85	13	15.3	77	19	24.7	162	32	19.8
Petersen	40	18	45.0	112	51	45.5	152	69	45.4
Total or average	278	46	16.5	339	94	27.7	617	140	22.7

The recovery rate of Petersen tags—45.4 percent—was outstanding, and for this tag the percentages of returns from illegal- and from legal-sized fish were nearly equal. It is apparent that lake trout marked with a Petersen tag, with the discs and ends of the pin projecting from each side near the point of miximum girth, were far more vulnerable to the fishery than were fish tagged by the other means employed in this study. The results possibly reflect also the greater conspicuousness of the Petersen tag, which often required considerable effort to disentangle from a net. Illegal fish marked with Petersen tags were commonly found dead in the meshes of both pound nets and gill nets from which they would otherwise have easily escaped. This fact may explain the similarity of recovery percentages between legal and illegal fish marked with this tag, whereas recoveries of illegal fish were relatively fewer for the other two types of tags. Probably the undersized fish marked with jaw tags or streamer tags were either able to escape legal fishing gear or were returned to the lake without detection of the mark.

The differences in rate of return from the several types of tags make difficult the estimation of the rate of harvest of lake trout tagged in the Apostle Island region in 1951. For reasons mentioned above, returns from Petersen tags probably do not provide a satisfactory estimate. Perhaps an appraisal based on the combined data for jaw and streamer tags (18.9 percent for fish of legal size when tagged) would provide the better estimate. This figure is undoubtedly conservative since no allowance is made for tagging mortality, loss of tags from fish, or failure of fishermen to detect or report tags (three tagged lake trout had reached retail fish markets before they were reported). Although there are no similar observations with which these data can be compared, the recovery rate during the first year after marking seems moderately high for a species with a life history as long as that of the lake trout.

Literature Cited

Fry, F. E. J.
1953. The 1944 year class of lake trout in South Bay, Lake Huron. Trans. Am. Fish. Soc., Vol. 82 (1952), pp. 178–192.

Joeris, Leonard S.
1953. Technique for the application of a streamer-type fish tag. Trans. Am. Fish. Soc., Vol. 82 (1952), pp. 42–47.

Rounsefell, George A., and John Lawrence Kask
1945. How to mark fish. Trans. Am. Fish. Soc., Vol. 73 (1943), pp. 320–363.

Schneberger, Edward
1936. Tagged trout reveal new facts and figures. The Fisherman, Vol. 5, No. 7, pp. 1–2.

Smith, Lester
1933. Tagging Lake Michigan fish. The Fisherman, Vol. 2, No. 5, pp. 3–4 and 11–12.

Smith, Oliver H., and John Van Oosten
1940. Tagging experiments with lake trout, whitefish, and other species of fish from Lake Michigan. Trans. Am. Fish. Soc., Vol. 69 (1939), pp. 63–84.

RELATIONSHIPS BETWEEN ALKALINITY AND ADSORPTION AND REGENERATION OF ADDED PHOSPHORUS IN FERTILIZED TROUT LAKES [1]

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ABSTRACT

To determine the practicability of fertilizing trout lakes in Michigan, series of applications of inorganic, commercial fertilizers were made to four trout lakes which ranged in methyl-orange alkalinity from 138 to 192 p.p.m. Two additional lakes, left unfertilized, were used as controls. Increases in epilimnial phosphorus content, which occurred as a result of fertilization, were only temporary; there was no evident difference between total phosphorus concentrations in the fertilized lakes and the unfertilized lakes during the summer following 2 years of fertilizer applications. The rate of disappearance of added phosphorus from epilimnial waters was shown statistically to be related to alkalinity. Increases in total phosphorous concentrations occurred within the hypolimnia and, up to a certain point, were correlated with the alkalinity of the lakes. The theoretical lower limit of the alkalitrophic, or excess calcium, condition seemed to be between 120 and 160 p.p.m. methyl-orange alkalinity. The postulate that the ratio of marl to organic matter is important in the control of adsorption and regeneration of phosphorus in lakes was supported. It was assumed that this factor, as well as the descent of phosphorus from epilimnial to hypolimnial layers, accounted for the nearly complete disappearance of added phosphorus from epilimnial waters of the fertilized trout lakes.

INTRODUCTION

One of the problems with which fishery biologists are concerned in their efforts to improve fishing conditions is that of increasing the supply of natural fish-food organisms. Fundamental to the food resources of all organisms are certain inorganic nutrients without which plants, the basic food organisms, could not exist. To increase the supply of these nutrients it has become common practice to fertilize lakes and ponds with commercial-grade inorganic fertilizers in much the same fashion that farmers fertilize fields.

The present investigation has been part of a series of studies initiated in 1946 by Prof. Robert C. Ball, of Michigan State College (see Ball, 1950), and continued with his assistance by Howard A. Tanner and the author. The overall objective of these studies has been to determine the

[1] This report constitutes a portion of a Dissertation accepted by the faculty of the Graduate School of Michigan State College in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Contribution Number 57 from the Department of Natural Science, Michigan State College.

practicability of fertilizing trout lakes in Michigan. The portion of the investigation reported in this paper deals with the effects of alkalinity on adsorption and regeneration of phosphorus added to the experimental lakes. A report of the effects of the fertilizer on biological productivity and on certain physical limnological features has been made by Tanner.[2]

Procedure

The lakes selected for the investigation are located in the Pigeon River Trout Research Area in Otsego and Cheboygan Counties, Michigan. Most of this area is covered with a well developed, second-growth jack pine and aspen forest. Some sections, however, support a second-growth hardwood forest. Five of the six lakes included in this study are within the pine-aspen region. They are South Twin, North Twin, West Lost, Lost, and Section Four. The sixth lake, Hemlock, is in the hardwood area. The soil of the pine-aspen region is sandy; the substratum is a brownish-yellow sand, with occasional gravel pockets. Seepage is rapid. The soil of the hardwood regions is a sand to sandy loam, with a substratum of reddish clay to sandy loam. This soil is more retentive of moisture than that of the pine-aspen region.

The lakes apparently originated as limestone sinks and are morphometrically similar; they range in area from 2.6 to 5.9 acres and in depth from 35 to 72 feet. None of the lakes has a surface inlet or outlet, unless it be Hemlock, which may have an intermittent outlet depending upon the lake level. With the exception of South Twin, each of the lakes was completely stratified and lacked oxygen in the lower hypolimnial waters during the summers of the investigation. South Twin Lake, although partially stratified, contained oxygen throughout the hypolimnion at all times.

Applications of inorganic, commercial fertilizers (6-10-4) containing superphosphate were made to the four lakes which were highest in alkalinity. North and South Twin lakes, which in 1948 had methyl-orange alkalinities of 34 and 74 p.p.m., respectively, were left unfertilized. Each of the other lakes received fertilizer. The amount applied varied with the alkalinity of the lake; the greater quantities were added to the lakes with the greater alkalinities. The average methyl-orange alkalinities at the surface of West Lost, Hemlock, Lost, and Section Four lakes in 1948 were 138, 163, 177, and 192 p.p.m. respectively; the concentrations of phosphorus applied to these lakes were 24, 40, 80, and 94 micrograms per liter, per application, respectively. The lakes were fertilized at 3-week intervals in 1949 and 1950. Applications were started in mid-June and continued until the end of July during each year. Thus three applications were made each year, or a total of six over the 2-year period. The quantity of phosphorus per application was estimated on the assumption that all the phosphorus added to the lakes would go into solution and become uniformly distributed throughout the lake.

[2] Tanner, H. A. (1952), Experimental fertilization of Michigan trout lakes. Ph.D. Thesis, Michigan State College.

Chemical analyses for total phosphorus concentrations were begun in May 1949 and continued at approximately 3-week intervals during the subsequent three summers. Samples were collected at the center of the lakes from (1) the surface, (2) the lower hypolimnion, within 3 feet of the bottom, and (3) the profundal soils. Water samples were obtained with the Kemmerer water sampler and soils with an Ekman dredge.

Total phosphorus concentrations of the water samples were determined according to the techniques of Ellis, Westfall, and Ellis (1946). Soil samples were analyzed for the adsorbed phosphate fraction by the technique of Bray and Kurtz (1945, method 2-A), after the soils were first prepared for analysis by drying at 60°C., and pulverizing with a mortar and pestle until fine enough to pass through a No. 35 sieve (0.50 millimeter). The Klett-Summerson photoelectric colorimeter was used for each of the above analyses. Percentage organic matter was determined by the wet-combustion procedure of Peech, *et al* (1947). Total methyl-orange alkalinity was measured by the procedure given in "Standard Methods for Examination of Water and Sewage" (1946). Dissolved oxygen was determined by the rapid unmodified Winkler method of Ellis, Westfall, and Ellis (1946).

Review of Literature

Juday, *et al.* (1927), after surveying 88 Wisconsin lakes which ranged in alkalinity from 1 to 44 milligrams of fixed carbon dioxide per liter, concluded that concentrations of soluble phosphates were not correlated with concentrations of carbonates.

Naumann (1932) proposed that lakes containing 100 p.p.m., or more, of CaO (equivalent to 179 p.p.m. methyl-orange alkalinity) be classified as alkalitrophic. He believed that low phytoplankton production in lakes of this type was due to phosphorus deficiency caused by the immobilization of this element by excessive quantities of calcium.

Schloesing (1900) and Gessner (1939) demonstrated precipitation of phosphorus in calcium carbonate solutions in laboratory experiments, and believed the precipitate to be tricalcium phosphate.

Hubault (1943), on the basis of investigations of certain Alpine lakes in Europe, suggested that Naumann's minimum limit of alkalitrophy was too high, and should be lowered to a value less than 100 p.p.m. CaO.

Deevey (1940), in a study of a number of Connecticut lakes, analyzed the statistical relationship between chlorophyll concentrations and alkalinity, and concluded that there was no significant effect of bicarbonate on plankton production except in hard-water lakes. The range in p.p.m. of bicarbonate of the hard-water lakes was from 122 to 148.

Effects of calcium on the adsorption of phosphate ions by iron-and-humus colloidal complexes were examined by Ohle (1937). On the basis of laboratory experiments this author proposed that in natural lakes marl would cause regeneration of phosphate ions by altering the electropotential on the colloidal interfaces.

Einsele (1941) conducted fertilization experiments on a German eutrophic lake (7.1 degrees alkalinity, German units, or equivalent to 127 p.p.m. methyl-orange alkalinity) and was unable to demonstrate significant increases in total phosphorus of epilimnial waters by the end of the second, or the third summer after adding phosphorus to the lake for two summers.

Hutchinson and Bowen (1947) added radioactive phosphorus to Linsley Pond, Connecticut, and found that 47 percent of the amount added had disappeared from the epilimnion within a week.

Coffin, *et al.* (1949), after adding radioactive phosphorus to an acid-bog lake in Nova Scotia, reported that adsorption occurred within minutes and hours, not days and weeks. They concluded, because of this rapid uptake, that measurements of dissolved inorganic phosphorus concentrations could not be used as criteria for establishment of fertility levels.

Residual Phosphorous Under Different Limnological Conditions

The total phosphorus concentrations of epilimnial waters during the 3 years of the investigations are presented in Table 1. During the first year of fertilization the average concentrations of total phosphorus in the fertilized lakes ranged from 20.0 to 141.0 micrograms per liter, whereas the unfertilized lakes averaged less than 10.0 micrograms per liter. In general, no appreciable difference in the averages between the two groups of lakes occurred during the second year of fertilization, 1950, or the year following fertilization, 1951. In 1950, concentrations in the unfertilized lakes ranged from 67.5 to 91.4 micrograms per liter, whereas the fertilized lakes had averages ranging from 59.7 to 97.1 micrograms per liter. The extraordinarily high phosphorus levels of the unfertilized lakes in 1950, as contrasted with 1949 and 1951, are attributed to unusually heavy rains of that year and the porous and acid nature of the soils surrounding the lakes. The averages of the 1951 phosphorus levels in the fertilized lakes were between 7.4 and 16.7 micrograms per liter, or of the same order of magnitude as those of the unfertilized lakes—7.7 and 11.7 micrograms per liter. These results are essentially in agreement with those of Einsele (1941), Hutchinson and Bowen (1947), and Coffin *et al.* (1949) who also demonstrated small or insignificant increases in the phosphorus content of natural lakes following fertilization.

To determine if a relationship existed between alkalinity and the rate of disappearance of the added phosphorus from epilimnial waters, the percentage residual phosphorus for certain periods has been calculated and compared to average alkalinities of corresponding periods (Table 2). Because of the variability of phosphorus levels during periods of fertilization, the data selected for comparison were those representing conditions: (1) at the end of each summer; (2) the beginning of 1950 and 1951 seasons, and (3) the maximum values of 1951. Percentage residual phosphorus values were derived by multiplying by 100 the quotient obtained after dividing the theoretical phosphorus concentration (which should

TABLE 1.—*Concentrations of total phosphorus (micrograms per liter) in epilimnial waters*

Period of analysis	Unfertilized lakes		Fertilized lakes			
	North Twin	South Twin	West Lost	Hemlock	Lost	Section Four
1949 May 1	7.5	.....	10.0	27.5	10.0	10.0
June 11–17	7.5	.....	10.0	30.0	14.0	5.7
June 18–22	5.0	.....	27.5	52.5	37.5	73.3
July 27–28	7.5	.....	15.0	525.0	25.0	55.0
July 29–30	4.0	.....	40.0	.....	80.0	110.0
Aug. 22–23	15.0	5.0	17.5	70.0	50.0	55.0
Average	7.8	5.0	20.0	141.0	36.1	51.5
1950 Mar. 23–24	54.5	22.6	38.2	57.5	20.3	14.0
June 14–15	14.0	38.8	23.4	22.0	28.1	19.7
June 18–19	134.0	24.0	151.0	135.0	196.0	83.5
July 6– 7	142.0	161.0	98.0	230.0	210.0	147.0
July 10–11	41.7	105.0	37.9	110.0	55.0	70.0
Aug. 28–29	19.0	197.0	17.0	39.4	18.4	23 8
Average	67.5	91.4	60.9	97.1	88.3	59.7
1951 Mar. 3	14.6	22.4	12.3	3.1	49.3	24.6
June 12–14	4.0	7.0	4.8	17.6	4.0	1.6
July 6– 8	4.5	9.8	9.8	12.1	24.2	6.1
July 30–31	6.2	7.8	3.1	18.6	3.8	23.4
Aug. 20–21	9.4	10.9	7.8	5.0	2.5	2.5
Average	7.7	11.7	7.4	11.3	16.7	11.6
Grand average	27.7	51.6	29.4	83.1	47.0	40.9

TABLE 2.—*Percentage residual phosphorus and average alkalinity (p.p.m.) in fertilized lakes during certain periods*
[With analysis of variance of percentage residual phosphorus and regression analysis of percentage residual phosphorus on average alkalinity]

Period of examination	West Lost		Hemlock		Lost		Section Four	
	Phosphorus percentage	Alkalinity (p.p.m.)	Phosphorus percentage	Alkalinity (p.p.m.)	Phosphorus percentage	Alkalinity (p.p.m.)	Phosphorus percentage	Alkalinity (p.p.m.)
June 12, 1949 to Aug. 23, 1949	23	120	56	135	20	144	18	159
June 12, 1949 to June 14, 1950	30	122	18	132	11	143	7	160
June 14, 1950 to Aug. 29, 1950	24	122	32	117	8	120	8	152
June 14, 1950 to June 12, 1951	7	119	15	111	2	121	1	153
June 12, 1949 to Maximum[1] 1951	7	120	8	119	5	130	4	160
June 12, 1949 to Aug. 21, 1951	5	118	2	118	1	127	0	161

Source of variability	Degrees of freedom	Sum of squares	Mean square	*F* ratio
Analysis of variance				
Total	23	3,913		
Lakes	3	936	312	[2]5.1
Periods	5	2,064	413	[3]6.8
Error	15	913	61	
Regression analysis				
Between lakes	3	945		
Regression on alkalinity	1	554	554	[3]9.1
Deviation from regression	2	391		
Error	15	913	61	

[1] Date of occurrence of maximum percentage residual phosphorus during the summer of 1951
[2] Significant at the 5-percent level
[3] Significant at the 1-percent level

have resulted from fertilization) into the units representing the concentration actually present. The results for the first four periods (Table 2) were based on total quantities of phosphorus added during the 12 months previous to the period of analysis, and the results of the last two periods (1951) were based on total quantities applied during the entire previous 2 years. These calculated values are, of course, only estimates of residual amounts, for it was empirically impossible to separate the fraction of fertilized phosphorus from that fraction that would have been present had none been artifically added.

An analysis of variance (based on procedures given by Snedecor, 1946) indicates significant variation (at the 5-percent level) between residual phosphorus concentrations of the different lakes. A comparison of the percentages of residual phosphorus with methyl-orange alkalinities shows that, in general, with higher alkalinities the residual phosphorus percentages were lower. A regression analysis (Snedecor, 1946) of this relationship demonstrates statistical significance at the 1-percent level. Although other variables, such as lake morphometry, biological activity . . . . also may have been significantly related to the disappearance of phosphorus, the present study provides strong support for the general hypothesis of the immobilization of phosphorus in natural lakes by calcium. The data of Table 2 suggest that this immobilization is more pronounced as alkalinities increase above 120 p.p.m. Naumann's (1932) minimum limit of alkalitrophy, as later modified by Hubault (1943), under certain conditions, therefore, may be as low as 120 p.p.m. However, more data are needed before an absolute lower limit of alkalitrophy can be stated. Other factors, as indicated below, may interfere with the calcium-phosphate precipitation mechanism and thereby increase the difficulty of assigning to a single ecological factor, such as alkalinity, the role of an "index" criterion in studies of lake nutrition.

Samples of water taken from lower hypolimnial regions and analyzed for total phosphorus (Table 3) revealed no marked differences between the fertilized and unfertilized lakes in 1949, although during 1950 and 1951 marked increases occurred in the fertilized lakes. Reference to the upper portion of Figure 1 indicates that, with one exception, the increases in hypolimnial phosphorus which occurred in the fertilized lakes were generally correlated with rate of application and alkalinity of lakes. The correlation between rate of application and increase of phosphorus was, of course, to be expected. Of particular interest, however, is a comparison of residual phosphorus percentages with alkalinities. The residual phosphorus percentages, when determined on the basis of the total amount put into the lakes, and the average amount present during 1951, were as follows: West Lost 43.0; Hemlock 121.2; Lost 170.5, and Section Four 13.3. Thus, with the exception of Section Four, the lakes with the greatest percentage residual phosphorus were those of highest alkalinity. The organic-matter contents of the profundal sediments of these lakes (except Section Four) were over 40 percent (Table 4). In the spring of 1950 a layer of a sand-

TABLE 3.—*Concentrations of total phosphorus (micrograms per liter) in hypolimnial waters*

Period of analysis	Unfertilized lakes		Fertilized lakes			
	North Twin	South Twin	West Lost	Hemlock	Lost	Section Four
1949 June 11–17	67.5	.....	17.5	62.5	70.0	5.0
June 18–22	51.0	.....	57.5	.....	32.5	15.5
July 27–28	52.5	.....	45.0	37.5	30.0	17.5
July 29–30	65.0	.....	72.5	50.0	40.5	40.0
Aug. 22–23	17.5	12.5	75.0	20.0	55.0	22.5
Average	50.7	12.5	53.5	42.5	45.6	21.0
1950 Mar. 23–24	55.0	34.3	53.0	39.0	.....	18.7
June 14–15	7.0	103.0	37.2	240.0	137.0	90.5
June 18–19	73.0	91.5	132.0	283.0	322.0	65.6
July 6– 7	79.0	141.0	166.0	200.0	640.0	140.0
July 10–11	48.0	48.0	127.0	280.0	366.0	56.0
Aug. 28–29	56.0	11.0	3.0	12.5	100.0	153.0
Average	53.0	71.5	86.4	175.7	224.0	87.3
1951 Mar. 3	22.4	46.3	33.9	47.0	218.0	26.2
June 12–14	2.4	8.0	40.0	217.0	800.0	33.6
July 6– 8	21.0	6.1	75.6	450.0	1,005.0	46.0
July 30–31	20.2	46.0	31.0	355.0	975.0	174.0
Aug. 20–21	7.8	10.2	142.0	430.0	1,180.0	109.0
Average	14.7	23.3	64.5	299.0	835.6	77.7
Grand average	40.3	46.5	69.3	181.6	398.1	63.6

clay-marl mixture was deposited over the bottom of Section Four Lake when a portion of the bank collapsed. As a result the organic-matter content in the bottom muds changed from 42 to 6 percent.

These data support the hypothesis of Ohle (1937) who, after demonstrating in laboratory experiments a release of phosphate ions from iron colloid particles upon the addition of calcium, predicted that marl would cause phosphorus regeneration in lakes in which the organic or iron colloids were abundant. Because phosphorus concentrations in Section

TABLE 4.—*Percentage organic matter in profundal soils of the six experimental lakes*

Year	Unfertilized lakes		Fertilized lakes			
	North Twin	South Twin	West Lost	Hemlock	Lost	Section Four
1949	57	60	51	47	46	42
1950	58	58	48	58	39	[1]6

[1] See text

Four, the extremely alkaline lake, were very low, this lake cannot be included within the calcium-induced phosphate-regeneration category of Ohle, but is more probably within Naumann's alkalitrophic category. A lake which stratifies may, like Section Four, be alkalitrophic throughout all thermal layers, whereas others, like Lost Lake may be alkalitrophic within the epilimnion but not in the hypolimnion. It appears probable that Naumann's (1932) proposed lower limit of alkalitrophy is, as already suggested by Hubault (1943), too high, because the average methyl-orange alkalinity of Section Four Lake for the 3-year period of this study was 161 p.p.m.

The results of the analyses of the adsorbed-phosphate fraction of the profundal soils are given in the lower portion of Figure 1. There was, in general, an inverse relationship between the amount of phosphorus added and the degree of increase in the different lakes; the lakes receiving the least amounts had greatest increases whereas the lakes receiving largest quantities showed little or no measureable increases. The relationship between the phosphate concentrations of the different lakes and the lake alkalinities was inverse: that is, the lakes with the lowest alkalinities had the highest concentrations of adsorbed phosphate. Another important relationship may be noted by reference to Figure 1. As time progressed, phosphate concentrations in the least alkaline lakes increased significantly, whereas those in the lakes with highest alkalinities did not.

On the basis of the data obtained in this study, three main hypotheses seem valid. (1) The capacity of lake sediments for exchangeable forms of phosphates is a function of the ratio of marl to organic matter—as the ratio increases the capacity decreases. (2) The phosphorus which was added to the lakes through fertilization accumulated in either the hypolimnial waters or in the sediments. In the lakes in which the sediments

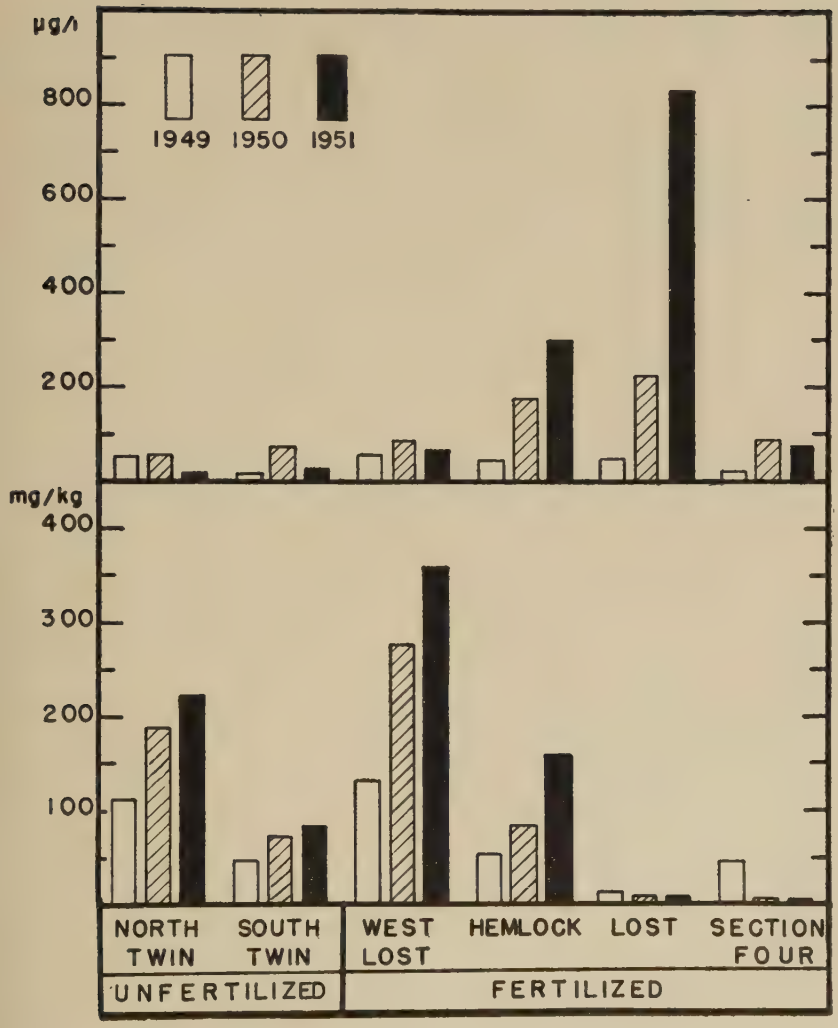

FIGURE 1.—A comparison of concentrations of hypolimnial total phosphorus and of adsorbed phosphorus in profundal soils in six lakes over a period of 3 years. The upper portion of the figure shows hypolimnial phosphorus (micrograms per liter). The lower portion shows profundal phosphorus (milligrams per kilogram of air-dry soil).

were high in organic matter and low in marl much of the phosphorus was adsorbed by the bottom sediments and remained in the exchangeable form; in lakes in which sediments were high in organic matter and also high in marl the phosphorus accumulated in both hypolimnial waters and in the

sediments, and in the lake in which the sediments were very low in organic matter and very high in marl the phosphorus did not accumulate in either the hypolimnial waters or in the adsorbed form in the sediments, but probably became fixed in insoluble precipitates. (3) The relationship between concentrations of available phosphorus in the lake sediments and concentrations of phosphorus in the lake waters was so variable, as indicated by Figure 1, that the practice of using measurements of available nutrients of lake-bottom muds as sole criteria for estimating productivity of lakes, as attempted by Roelofs (1944) and Wohlschlag (1950), cannot be entirely justified. Neess (1949), in a review of the literature of pond fertilization studies in Europe, indicated that German investigators, as long as 50 years ago, had demonstrated reduction in adsorptive capacity of colloidal humus and release of adsorbed nutrients upon addition of lime. The results of the present study support the assumption that this mechanism is an important nutrient regulator in natural lakes.

In conclusion, it does not seem feasible to expect a many-fold increase in phosphorus contents of trout lakes from fertilization. It has been shown in this and other studies that nearly 100 percent of added phosphorus disappears from epilimnial waters within a year following application. Where it is desired to maintain high phosphorus levels, it usually will be necessary to make continual applications to offset sinking to hypolimnial waters and adsorption by bottom sediments. There is, however, a hypothetical situation under which it should be possible to attain high phosphorus concentrations with only occasional and infrequent applications. A lake which does not stratify and which has sediments of low phosphate-adsorptive capacities combined with a propensity for high rates of phosphate regeneration should meet this specification. Evidence indicates that these conditions are most likely to exist in those lakes in which the sediments consist of high concentrations of both marl and organic matter, and in which the alkalinity approaches the lower limit of alkalitrophy. In this regard it is interesting to note the observations of Ball (1948) who reported " . . . there seems to be a positive correlation between alkalinity and fish production. . . . hard-water lakes (above 150 p.p.m. methyl-orange alkalinity) have an average poundage per acre that is higher than for either of the other groups (soft and intermediate)."

Thus, although there has been much speculation about the relationship between alkalinity and productivity in lakes, there seems to be good reason to accept the rule-of-thumb concept that, up to a certain as yet undefined limit, hard-water lakes are often the best producers. The maximal limit of this optimal range is controlled, according to the conclusions of Naumann, by the immobilization of phosphorus through the action of excess calcium. The evidence of Hubault (1943), Deevey (1940), and the present study indicates that alkalitrophy may exist below 180 p.p.m. methyl-orange alkalinity, and may even occur at 120 p.p.m. Ohle's (1937) postulate, which is given presumptive support by the present study, serves as a partial explanation for the high rates of phosphorus regeneration in waters

of high alkalinity and also provides a reasonable explanation for the difficulty in determining precisely the concentrations at which calcium actually becomes excessive.

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Literature Cited

American Public Health Association
1946. Standard methods for the examination of water and sewage. 9th edition, New York. 286 pp.

Ball, Robert C.
1948. A summary of experiments in Michigan lakes on the elimination of fish populations with rotenone, 1934–1942. Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 139–146.
1950. Fertilization of natural lakes in Michigan. Trans. Am. Fish. Soc., Vol. 78 (1948), pp. 145–155.

Bray, Roger H., and L. T. Kurtz
1945. Determination of total. organic and available forms of phosphorus in soils. Soil Sci., Vol. 59, pp. 39–45.

Coffin, C. C., F. R. Hayes, L. H. Jodrey, and S. G. Whiteway
1949. Exchange of materials in a lake as studied by the addition of radioactive phosphorus. Can. Jour. Res., D, Vol. 27, pp. 207–222.

Deevey, Edward S., Jr.
1940. Limnological studies in Connecticut. V. A contribution to regional limnology. Am. Jour. Sci., Vol. 238, pp. 717–741.

Einsele, Wilhelm
1941. Die Umsetzung von zugeführtem, anorganischen Phosphat im eutrophen See und ihre Rückwirkungen auf seinen Gesamthaushalt. Zeitschr. für Fisch. Bd. 39, S. 407–488.

Ellis, M. M., B. A. Westfall, and Marion D. Ellis
1946. Determination of water quality. U. S. Dept. Inter., Fish and Wildlife Serv., Research Rep. 9, 122 pp.

Gessner, Fritz
1939. Die Phosphorarmut der Gewässer und ihre Beziehung zum Kalkgehalt. Internat. Rev. der ges. Hydrob. und Hydrogr., Bd. 38, S. 203–211.

Hubault, Etienne
1943. Les grands lacs subalpins de Savoie sont-ils alkalitrophes? Arch. Hydrobiol., Bd. 40, S. 240–249.

Hutchinson, G. Evelyn, and Vaughan T. Bowen
1947. A direct demonstration of the phosphorus cycle in a small lake. Proc. Nat. Acad. Sci., Vol. 33, pp. 148–153.

Juday, C., E. A. Birge, G. I. Kemmerer, and R. J. Robinson
1927. Phosphorus content of lake waters of northeastern Wisconsin. Trans. Wis. Acad. Sci. Arts, and Lett., Vol. 23, pp. 233–248.

Naumann, E.
1932. Grundzüge der regionalen Limnologie. Die Binnengewässer, Bd. 11, 176 S.

Neess, John C.
1949. Development and status of pond fertilization in central Europe. Trans. Am. Fish. Soc., Vol. 76 (1946), pp. 335–358.

Ohle, Waldemar
1937. Kolloidgele als Nährstoffregulatoren der Gewässer. Die Naturwissensch., Bd. 25, S. 471–474.

Peech, Michael, L. T. Alexander, L. A. Dean, and J. Fielding Reed
1947. Methods of soil analysis for soil-fertility investigations. U. S. Dept. Agr., Circ., No. 757, 25 pp.

Roelofs, Eugene W.
1944. Water soils in relation to lake productivity. Mich. State Coll., Agr. Exp. Sta., Tech. Bull. 190, 31 pp.

Schloesing, Th.
1900. L'acide phosphorique en présence des dissolutions saturées de bicarbonate de chaux. C. R. Acad. Sci., Vol. 131, pp. 211–215.

Snedecor, George W.
1946. Statistical methods. 4th ed. The Iowa State College Press, Ames, Iowa. 485 pp.

Wohlschlag, Donald E.
1950. Vegetation and invertebrate life in a marl lake. Invest. Indiana Lakes and Streams, Vol. 3, pp. 321–372.

ABUNDANCE, GROWTH, AND CONDITION OF YELLOW BASS, *MORONE INTERRUPTA* GILL, IN CLEAR LAKE, IOWA, 1941 TO 1951 [1]

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ABSTRACT

Scales and data were collected on over 3,500 Clear Lake yellow bass in 1941–1943, and 1947–1951. In 1941 to 1943 most of the yellow bass in the angler's catch were from the 1939 year class with a few from the 1937 year class. From 1945 to 1951, angling, seining, and gillnetting showed no marked change in the abundance of yellow bass. The 1938, 1940, 1941, 1947, and 1950 year classes contributed few or no fish to the later catches. In 1947 and in 1950 young of the year, were present but apparently few of these fish survived 1 year. The 1939, 1943, 1946, 1948, and 1949 year classes were particularly abundant. Young yellow bass were larger in early July during the years with above normal June air temperatures than during years with cool June temperatures. Most growth in length occurs in the first three years of life. The growth rate decreased from 1937 to 1949 but was more rapid again in 1950 and 1951. In 1947 growth was slow until after July 1, probably as a result of low May and June temperatures. In 1949 little growth took place from July 1 to August 26. In 1948 and 1949 the ponderal index decreased as the season progressed, but this trend was lacking in 1947, 1950, and 1951.

INTRODUCTION

The fishes of Clear Lake, Iowa, have been studied periodically since 1941 to ascertain the changes in their abundance, growth, and condition. It is hoped that a continued study of this one lake may show how these changes can be controlled to provide better fishing.

Clear Lake in Cerro Gordo County, north-central Iowa, is a eutrophic lake with a miximum depth of approximately 20 feet. It is about 5 miles long, east-west, is slightly over 2 miles at the widest portion and has a total area of 3,643 acres. The lake is used intensively for recreational purposes.

Two state parks provide general access to the public. Public highways also border the lake at many spots providing further access and the State Conservation Commission maintains two public docks. Private homes and

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cottages border about 42 percent of the shore line. Resorts and cabin camps, with access to about 20 percent of the shoreline enjoy a thriving tourist business. In addition to the fishing, boating and swimming provide much recreation on the lake.

Yellow bass, probably introduced into Clear Lake with other fish from the Mississippi River, were first reported from anglers' catches about 1932 (Bailey and Harrison, 1945). During some years the yellow bass have supported most of the angling. May and June creel-census investigations indicated that yellow bass comprised 33 percent of the catch in 1948, 46 percent in 1949, 24 percent in 1950, and 10 percent in 1951 (Rose, 1951). Later in the summer the yellow bass usually comprise a higher proportion of the catch.

Abundance

Yellow bass were collected by a number of methods in an attempt to sample all size- and age-classes. The 1947 to 1951 collections were more comprehensive than in the earlier years; experimental gill nets, hoop nets, wire traps, a 50-foot bag seine, and minnow seines were used.

The Biology Survey Crew of the Iowa State Conservation Commission has made 2 to 4 seine hauls with a 500-foot seine each year since 1945 in late July or August (Table 1). The numbers of young yellow bass were

Table 1.—*Abundance of yellow bass in Clear Lake as indicated by various sampling methods*

Year	Number of fish per haul of a 500-foot seine[1]			Catch per man-hour of angling[2]	Catch per hour in gill net[3]
	Young	Yearlings	Adults		
1945	2,525	0	1.0	....	....
1946	1,168	48	1.6	....	....
1947	165	64	1.0	....	0.59
1948	270	0	5.8	0.42	0.32
1949	1,909	37	2.3	0.51	0.80
1950	429	60	2.5	0.27	2.56
1951	1,361	0	15.0	0.14	1.14

[1] Data from Iowa State Conservation Commission Biology Survey Crew, through the courtesy of Everett B. Speaker, Earl Rose, and Tom Moen
[2] Rose (1951)
[3] Each gill net 125 feet long and consisting of equal lengths of the following meshes, extension measure: 1½, 2, 2½, 3, 4 inches

relatively low in 1947, 1949, and 1950 and no yearling yellow bass were taken in 1945 and 1948. The gill nets fished by the Iowa Cooperative Fisheries Research Unit personnel capture few young-of-the-year yellow bass but presumably take most of the larger yellow bass in relation to their abundance. A comparison of the numbers of adult yellow bass taken in the seines, gillnets and by angling (Table 1) does not show any clear-cut trend or change in the population from 1945 to 1951. Possibly there was an increase in adult bass in 1950 and 1951.

Abundance of Year Classes

Early in the investigations it was recognized that there were pronounced differences in the numbers of yellow bass which hatched in different calendar years and survived to catchable size. Most of the yellow bass collected from 1941 to 1944 were hatched in 1939 (Bailey and Harrison, 1945; Lewis and Carlander, 1948). An analysis of the scales of yellow bass collected from 1947 to 1951, shows that during these years the yellow bass population was not so clearly dominated by one year class (Table 2).

Table 2.—*Age-class composition of yellow bass from Clear Lake in different years of collection*

Year collected	Number of specimens	Percentage in each age group[1]						
		I	II	III	IV	V	VI	VII
1941	96	....	96.9	....	3.1	....	....	....
1942	169	....	....	94.1	....	5.9	....	....
1943	25	....	....	....	100.0	....	....	....
1947	152	21.7	17.1	11.2	32.9	14.5	2.6	....
1948	421	0.2	52.6	29.9	4.5	3.3	9.3	0.2
1949	1,360	60.1	0.1	35.9	2.4	1.0	0.4	0.1
1950	380	40.0	53.9	5.0	1.1	....	....	....
1951	901	....	82.4	13.6	1.3	2.7	....	....
Combined	3,504	28.6	36.7	22.4	4.1	6.7	1.4	0.1

[1] To determine year of origin, subtract age from year of capture

Although the sampling methods used in different years prevent exact evaluation of the abundance of the various year classes, it is obvious that certain year classes were much more successful than others. The 1942 and 1943 year classes were apparently quite abundant since fish of age-groups V and IV were still plentiful in 1947. The 1946, 1948, and 1949 year classes also seem to have been successful. The success of the various classes can probably be classified as follows:

Very successful	*Moderate*	*Unsuccessful*
1939	1937	1938
1942	1944	1940
1943	1945	1941
1946		1947
1948		1950
1949		

A comparison of these data with the available information on abundance of young fish indicates that reproduction is not the principal factor controlling the success of a year class. The State Biology Survey Crew found young yellow bass to be more abundant in 1945, 1946, and 1949 than in 1947, 1948, and 1950 (Table 1). The 1946 and 1949 year classes were particularly successful but probably no more so than the 1948 year class. The Cooperative Research Unit biologists found young yellow bass to be

fairly abundant in 1950 but took no yearlings in 1951. It is believed that unsuccessful reproduction of yellow perch in 1950 (Carlander, 1951) may have caused a greater predation on the young yellow bass which resulted in their elimination in fall and winter.

Growth of Young-of-the-Year Yellow Bass

Young yellow bass were collected with minnow seines and measured at 1- or 2-week intervals to determine their growth through the season (Fig. 1, Table 3). The growth from early July through September for each year can be represented fairly accurately by a straight line (Table 3). Only the November collections deviate from the lines, indicating that the growth had stopped or greatly slowed down about October first. Yellow bass probably spawn in Clear Lake in late May or early June. The years

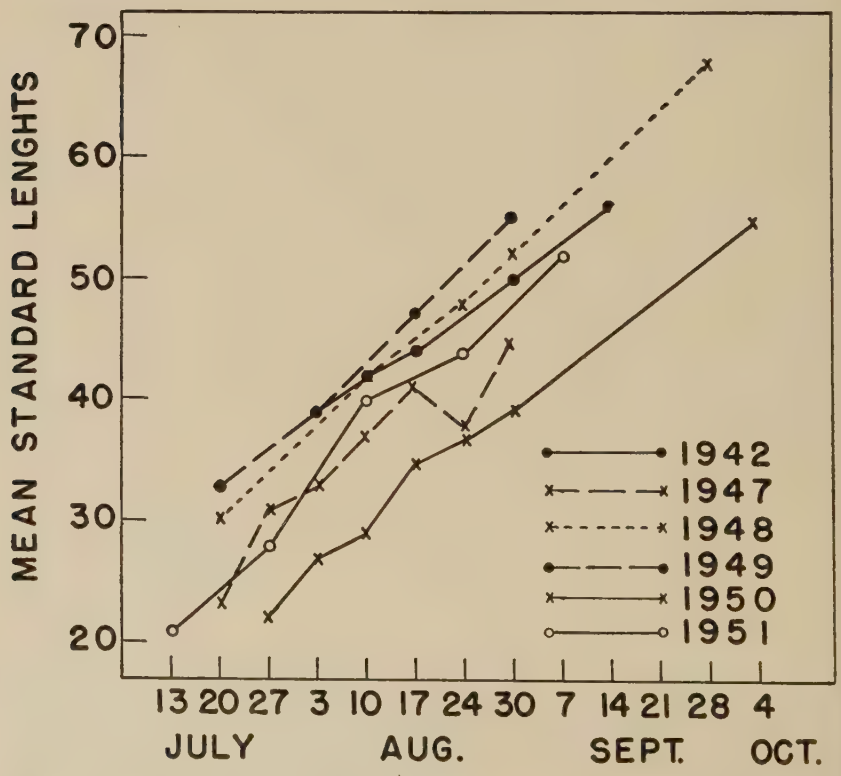

Figure 1.—Sizes of young-of-the-year yellow bass at 2-week intervals, in Clear Lake, Iowa, during the summers of 1942 and 1947–1951. On November 5, 1942, the average length of 41 yellow bass was 62 millimeters, indicating that growth stopped sometime in September or October.

TABLE 3.—*Mean standard lengths in millimeters of yellow bass during their first summer in Clear Lake, Iowa, and corresponding mean monthly air temperatures*

[Number of specimens in parentheses. X designates a computed length]

Year	Mean standard lengths during weeks centering on													Line formulae[1]		Mean temperatures (F.°)		
	July			August					September			Oct.	Nov.					
	13	20	27	3	10	17	24	31	7	14	28	4	2	*a*	*b*	June	July	Aug.
1942	33 X	..	39 (10)	42 (14)	44 (20)	..	50 (105)	..	56 (36)	..	..	..	62 (41)	16	2.82	67	71	70
1943	28 (216)	36 (79)	..	..	..	..	..	..	..	..	..	..	68 (58)	..	....	70	73	71
1947	23 (24)	31 (18)	33 (38)	37 (14)	41 (22)	38 (78)	..	45 (47)	..	..	..	..	..	7	3.14	64	71	78
1948	30 (954)	..	..	42 (139)	..	48 (167)	52 (100)	..	..	..	68 (100)	..	..	7	3.76	67	74	73
1949	33 (37)	..	39 (10)	..	47 (64)	..	55 (51)	..	..	..	..	..	..	10	3.70	71	74	72
1950	20 X	22 (12)	27 (64)	29 (83)	35 (47)	37 (110)	39 (88)	..	..	..	..	55 (3)	..	1	3.22	66	67	66
1951	21 (142)	..	28 (144)	..	40 (196)	..	44 (76)	..	..	52 (183)	..	..	..	2	3.90	63	70	67

[1] Standard length = a + b (number of weeks after June 3)

in which the yellow bass were large when first collected in early July (1942, 1948, and 1949) were years with higher than average June temperatures. The regression coefficient between mean June temperature and mean lengths of yellow bass on July 13 was 2.416 ± 0.176 which indicates that the lengths of the yellow bass could have been predicted with a rather high degree of accuracy from the mean June temperatures. No relationships were detected between July to August temperatures and the growth rates (as represented by *b*, the slopes of the lines) of the yellow bass during these months.

Body-Scale Relationships and Calculation of Growth

Scales for the assessment of age and growth were collected from the side of the body just below the lateral line even with the end of the pectoral fin. The dry scales were placed between two microscope slides and examined with a microprojector (Lewis and Carlander, 1949). The thicker older scales were usually soaked a short time in water to increase their translucency. In the study of the body-scale relationship all scales were soaked before measurement since it was found that soaking increased the diameters of the scales slightly.

The body-scale relationship of the yellow bass collected from 1941 to 1943 (Lewis and Carlander, 1948) was represented by a straight line with the intercept on the length axis at 16 millimeters. Analysis of the 1947, 1948, and 1949 data[3] indicated that in these samples, also, the body-scale relationship did not deviate greatly from straight lines with intercepts at 24, 18, and 21 millimeters, respectively. All computations of lengths at various annuli were made on a direct proportion basis using a nomograph with 16 millimeters rather than zero as a base (Carlander and Smith, 1944).

The calculated lengths at the various annuli correspond closely to the measured lengths of fish of the same year class collected near the time when the particular annuli were believed to have formed. The lengths computed at a given annulus from fish of the same year class but collected in different years were similar and did not show any definite tendency to decrease with increase in length of time since formation of the annulus, as has occurred in several scale growth studies (see Van Oosten, 1929, for discussion.) For example, the mean calculated lengths for the first year of the 1946 year class were 68, 64, 63, 62, and 64 millimeters for the 1947–1951 collections, respectively; and for the second annulus the calculated lengths were 113, 115, 115, and 113 millimeters for the 1948 to 1951 collections.

Annual Growth in Length

Most of the growth in length occurs in the first 3 years with very little growth in subsequent years (Fig. 2, Tables 4 and 5). The average growth

[3] Only 191 of the fish collected in 1949 were included in this analysis.

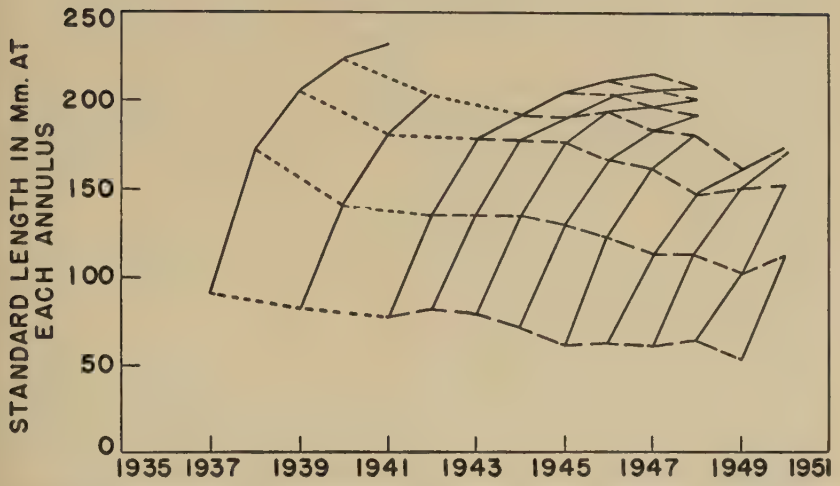

FIGURE 2.—Growth of 1937 to 1949 year classes of yellow bass, Clear Lake, Iowa.

is less than 1 inch per year after the third year. The greatest increase in weight, on the other hand, occurs in the third and fourth years. The weight of the average yellow bass more than doubles during the third year.

The rate of growth decreased decidedly from 1937 to 1949. At the end of the second year of life, the 1948 year-class fish were only 60 percent as long as the 1937 year class fish at the same age. Probably this decline was associated with an increase in numbers of yellow bass. The yellow bass were apparently just becoming established in the 1930's and possibly intraspecific competition was less than it has been since 1940.

TABLE 4.—*Average calculated lengths of Clear Lake yellow bass of year classes, 1937 to 1949*

Year class	Number	Average calculated standard length (millimeters) at end of year of life						
		1	2	3	4	5	6	7
1937	13	91	173	206	224	232	...	...
1939	277	84	141	181	203	...	...	...
1941	5	79	137	179	194	205	212	216
1942	63	82	136	178	191	203	208	209
1943	69	80	136	177	196	198	201	...
1944	50	72	131	168	185	193	...	...
1945	198	62	124	163	181	...	...	...
1946	792	63	114	149	161	174	...	...
1947	33	62	115	151	171	...	...	...
1948	1146	65	103	154	...	...	...	...
1949	892	55	112	...	...	...	...	...
Total	3538	64	118	161	189	198	208	211
Total length (inches)		3.14	5.79	7.90	9.28	9.72	10.21	10.36
Weight (grams)[1]		6	45	121	202	234	274	287
Weight (ounces)		0.2	1.6	4.3	7.1	8.2	9.7	10.1

[1] Computed from: log weight = −4.959+3.191 log standard length

TABLE 5.—*Annual increments of growth in length of Clear Lake yellow bass of various year classes*

Year class	Number	Average annual increment (millimeters) during year of life[1]						
		1	2	3	4	5	6	7
1937	13	91	82	33	18	9	..	..
1939	277	84	57	42	16	..	..	..
1941	5	79	58	42	15	11	7	10
1942	63	82	54	42	13	12	10	7
1943	69	80	56	41	19	11	9	..
1944	50	72	59	37	16	10	..	..
1945	198	62	62	39	17	..	..	..
1946	792	63	51	35	13	13	..	..
1947	33	62	53	36	17	..	..	..
1948	1146	65	39	50	..	..	..	..
1949	892	55	58	..	..	..	..	..
Unweighted mean		72	57	40	16	11	9	8
Weighted mean		64	54	39	16	12	10	8
Number of fish		3,538	2,535	1,249	295	137	52	3
Total length (inches)		3.14	2.65	1.91	0.79	0.59	0.49	0.39
Weight (grams)		6	39	71	50	42	40	33
Weight (ounces)		0.2	1.4	2.5	1.8	1.5	1.4	1.2

[1] The increments in this table are not necessarily the differences between the lengths at corresponding annuli from Table 4. For example, the average length at the first annulus of the 1948 year class is based upon 1,146 fish whereas that at the second annulus is based upon 329 fish. The increment during the second year is based upon the growth of only these 329 fish.

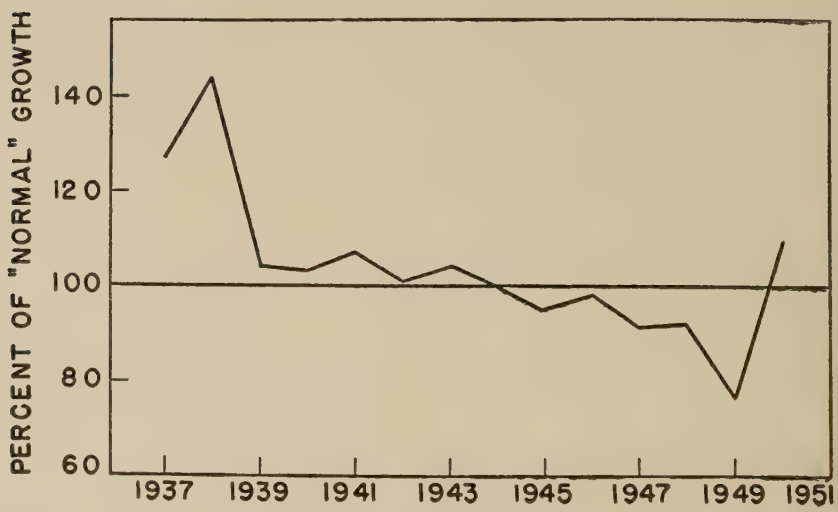

FIGURE 3.—Relative amount of growth in various calendar years, 1937 to 1950, of yellow bass, Clear Lake, Iowa. (Growth index determined by dividing the annual increments for the various age groups present in the given year by the unweighted mean annual increments for the same years of life).

TABLE 6.—*Comparison of amount of growth of Clear Lake yellow bass in various calendar years*

Year	Growth index[1]	Year	Growth index
1937	126	1944	100
1938	144	1945	95
1939	104	1946	98
1940	103	1947	91
1941	107	1948	92
1942	101	1949	77
1943	104	1950	111

[1] Growth index determined by dividing the annual increments for the various age groups present in the given year by the unweighted mean annual increments for the same years of life

The 1950 growth was apparently more rapid again, as is shown by the second-year growth of the 1949 year class, the third-year growth of the 1948 year class and the fourth- and fifth-year growth of the 1947 and 1946 year classes, respectively. An index to the growth in various calendar years was computed by dividing the average annual increments for the given year by the unweighted mean annual increments for the same years of life (Fig. 3, Table 6). For example, the annual increments for 1950 were divided by the average increments for the second through the fifth years of life. The years 1945 to 1949 showed below-average growth with 1949 being a particularly poor year. No correlations between summer temperatures or rainfall and the annual growth of yellow bass were demonstrated. Apparently any increases in growth rate which might be expected to result from higher temperatures and longer growing season were less significant than the changes brought about by other factors, such as population density, for which quantitative measures are not available.

Growth During the Summer

Since specimens were collected at intervals throughout the summers of 1947 through 1951, it is possible to follow the seasonal growth of certain groups of fishes (Table 7). In most years at least one-third of the annual growth was completed before the first collections in June. The only exception was in 1947 when the fish were not much larger on July first than at the time of annulus formation. (The annuli apparently formed before the June collections each year, for there was little evidence of uncompleted annulus formation.) May and June mean temperatures at Mason City, Iowa, in 1947 were lower than in any other year in the study—53.2°F. and 63.8°F., or 5.1° and and 3.1° below normal, respectively.

Yellow bass of age-groups I and IV showed no growth from July 1 to August 26 in 1949, although the II-group yellow bass did show a slight amount of growth during this period.

The growth of all age groups was fairly rapid and uniform throughout the summer of 1951. The "normal" average annual increment was reached by July 1 by the age-groups III and V and by August 15 by age-group II.

TABLE 7.—*Growth of certain year classes of Clear Lake yellow bass during various summers*

Year of collection	Year class	Length of previous annulus	Mean standard length in millimeters at various periods							Length at next annulus
			June 4-17	June 18-July 1	July 2-15	July 16-29	July 30-Aug. 12	Aug. 13-26	Aug. 27-Sept. 9	
1947	1946	68*	.....	78*	96	99*	.....	.....	.....	114**
	1945	130*	.....	136*	135	155	154	162	.....	163**
1948	1946	113**	135	138	139*	141**	146*	145*	.....	149**
	1945	162**	168	171	170*	173*	175*	173*	.....	181*
1949	1948	65**	87*	96*	100**	102**	102**	101**	.....	103**
	1946	149**	157*	155*	157*	156*	161*	165*	.....	161*
	1945	182*	186	185	187	189	185	188	.....	193A
1950	1949	57**	.....	90*	92*	96*	99*	.....	.....	112**
	1948	102**	.....	120*	134*	137*	137	.....	.....	154**
1951	1949	112**	126*	133**	142*	141**	147**	151**	156*	152A
	1948	154**	163*	164*	172*	173*	176*	181*	184	170A
	1946	174*	183	176	183	187	190	199	200	183A

[The length at the previous annulus is the mean calculated length at the last annulus of the fish collected during the summer. The length at the next annulus is the mean calculated length for the next annulus on fish of the same year class collected in later years, except for those year classes where data for later years are not available. In the latter cases, marked "A", the length is that which would be attained if the annual increment were the same as the unweighted mean for the given year of life. Lengths marked ** are based upon over 100 specimens; those marked *, upon 10–99 specimens; and those not marked, on 1–9 specimens]

This more rapid growth and the above-average growth in 1950 (Table 6) should result in an improvement in the average size of the yellow bass in Clear Lake.

Length-Weight Relationship

The length-weight relationship for the yellow bass collected from 1941 to 1943 was described (Lewis and Carlander, 1948) by the formula:

$$\log W = -3.47237 + 2.548 \log L,$$

where W = weight in grams,
and L = standard length in millimeters.

The length-weight relationship appears to differ from year to year and the best fitting formulas (by the least squares method) for the relationship in various years were determined as:

$$1947 \quad \log W = -5.560 + 3.467 \log L.$$
$$1948 \quad \log W = -3.889 + 2.705 \log L.$$
$$1949 \quad \log W = -4.786 + 3.140 \log L.$$

A test of the regressions for these three years by the analysis of covariance (Snedecor, 1946, sections 12.3 and 12.5) showed that there was very little chance that the slopes of the regression line were the same the three years ($F = 8.56$ with 2 and 655 degrees of freedom). The adjusted mean weights differed somewhat but not sufficiently so that it could be said with 95-percent confidence that the mean weights for the mean length were different ($F = 2.97$ with 2 and 657 degrees of freedom).

For the estimation of weights at various lengths (as in Table 4) the following average length-weight regression based upon the 1947–49 collections was used:

$$\log W = -4.959 + 3.191 \log L.$$

Ponderal Indexes

The ponderal index, or coefficient of condition, K as computed from

$$K = \frac{W\ 10^5}{L^3},$$

where W = weight in grams,
and L = standard length in millimeters,

gives a convenient method of comparing the relative weights of fish at different seasons or in different years. If the average weight of the fish does not increase as the cube of the length, the ponderal index may vary with the length of the fish. For example, in 1948 when the weight increased as the 2.705-power of the length, the values of the ponderal index tends to decrease as the length of the fish increases, whereas in 1947 and 1949 when the weight increased more rapidly than the cube of the length, the

ponderal-index values tended to increase with the growth of the fish. For greatest accuracy, the index values should be compared for fish within specific size groups.

In 1948 and 1949 there was a well defined seasonal decrease in ponderal-index values (the fish grew thinner or lighter for their length) as the summer progressed (Table 8). In 1951, the ponderal index did not change

TABLE 8.—*Ponderal-index values for selected size groups of yellow bass during the summers of 1948, 1949, and 1951*

Year of collection	Standard length (millimeters)	Mean ponderal index, with number of specimens in parentheses					
		June 4-17	June 18-July 1	July 2-15	July 16-24	July 30-Aug. 12	Aug. 13-26
1948	100–149	3.41	3.30	3.13	3.02	2.79	....
		(3)	(8)	(114)	(28)	(37)	....
	150–199	....	2.88	2.92	2.87	2.79	....
		....	(2)	(93)	(29)	(61)	....
1949	70–129	2.65	2.65	2.57	2.50	2.39	2.32
		(42)	(95)	(172)	(208)	(168)	(141)
	140–159	2.88	2.90	2.83	2.77	2.77	2.68
		(36)	(78)	(70)	(69)	(55)	(37)
	160–179	2.63	2.67	2.74	2.67	2.63	2.61
		(15)	(31)	(22)	(18)	(39)	(40)
	180–229	2.38	2.56	2.55	2.40	2.36	2.45
		(23)	(4)	(22)	(10)	(13)	(21)
1951	130–149	3.09	3.30	3.24	3.31	3.31	3.33
		(7)	(102)	(39)	(99)	(134)	(29)
	150–179	3.18	3.38	3.35	3.51	3.39	3.36
		(13)	(39)	(18)	(27)	(70)	(24)
	180–209	3.43	3.73	3.50	3.82	3.83	3.56
		(1)	(3)	(3)	(8)	(19)	(10)

TABLE 9.—*Ponderal index values for yellow bass from Clear Lake, 1942 to 1951*

Size range (millimeters)	Year	Number of fish	Mean K	Range of K
100–149	1947	13	3.26	.....
	1948	190	3.06	1.63–5.57
	1949	543	2.52	1.59–3.20
	1950	241	3.10	1.92–3.85
	1951	500	3.29	1.89–3.94
150–199	1942	159	3.19	2.82–3.77
	1947	14	3.55	.....
	1948	185	2.87	1.66–4.83
	1949	490	2.70	1.96–3.17
	1950	22	2.93	2.70–3.33
	1951	404	3.37	2.45–4.30
100–199	1942	169	3.21	2.60–4.18
	1943	22	2.96	2.72–3.26
	1947	84	3.05	1.82–3.64
	1948	427	2.94	1.63–5.57
	1949	1423	2.58	1.59–3.48
	1950	389	2.95	1.92–3.85
	1951	911	3.33	1.89–4.30

during the summer and the less adequate data for 1947 and 1950 (not given in the table) also showed no seasonal change. It is perhaps of some significance that in 1949 the yellow bass showed practically no growth after July 1 and that in 1948 the growth during this period was slower than in 1947, 1950, or 1951.

The yellow bass were apparently in better condition, or heavier for their length in 1951 and in 1947 than during the other years and were in particularly poor condition in 1949 (Table 9). Tom Moen, in a typewritten report to the Iowa State Conservation Commission, commented on the concave abdomens and obvious loss of flesh above the lateral line of yellow bass collected from Clear Lake on February 17, 1950. The average ponderal index of 35 yellow bass which he examined was 2.69.

Acknowledgments

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Literature Cited

Bailey, Reeve M. and Harry M. Harrison, Jr.
1945. The fishes of Clear Lake, Iowa. Iowa State Coll. Jour. Sci., Vol. 20, pp. 57–77.

Carlander, Kenneth D.
1951. Clear Lake research notes. Iowa Conservationist, Vol. 10, p. 155.

Carlander, Kenneth D., and Lloyd L. Smith, Jr.
1944. Some uses of nomographs in fish growth studies. Copeia 1944, No. 3, pp. 157–161.

Lewis, William M., and Kenneth D. Carlander
1948. Growth of the yellow bass, *Morone interrupta* Gill, in Clear Lake Iowa. Iowa State Coll. Jour. Sci., Vol 22, pp. 185–195.
1949. A simple method of mounting scales. Prog. Fish-Cult. Vol. 11, p. 263.

Rose, Earl T.
1951. The 1951 Iowa lakes creel census. Iowa State Cons. Comm., Quart. Biol. Rep. Vol. 3, No. 2, pp. 8.

Snedecor, George W.
1946. Statistical methods. 4th Edition. Iowa State Coll. Press. Ames. 485 pp.

Van Oosten, John
1929. Life history of the lake herring (*Leucichthys artedi* Le Sueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. U.S. Bur. Fish., Vol. 44, pp. 265–428.

THE INCREASE IN GAME-FISH POPULATIONS IN EAST OKOBOJI LAKE, IOWA, FOLLOWING INTENSIVE REMOVAL OF ROUGH FISH

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ABSTRACT

Test seining in East Okoboji Lake, Dickinson County, Iowa, in 1940 revealed a large population of rough fish and relatively few game fish. The Iowa Conservation Commission therefore intensified its rough-fish removal activities on the lake. Following several years of this expanded program, significant increases of game fish occurred. These increases are reported in the form of comparative data on catch per unit effort over a period of 12 years, from 1940 to 1951. General observations indicated an improved environment for game fish and an increase in angling success.

INTRODUCTION

The purpose of this paper is to report some significant changes in game-fish populations in East Okoboji Lake following several years of intensive removal of rough fish. In 1940, test seining revealed that rough fish, including bigmouth buffalo (*Ictiobus cyprinellus*), carp (*Cyprinus carpio*), and freshwater drum or sheepshead (*Aplodinotus grunniens*), had become extremely abundant, and that game-fish populations were relatively low. This netting indicated that more intensive efforts should be made to reduce the populations of rough fish. To evaluate the vigorous program of removal that was subsequently established, State seining crews were required to record on census forms the number of pounds of each species of rough fish removed, and the number of each species of game fish returned to the lake from each haul of the seine and from each trap lift. The length and mesh size of seine used, the location of each haul, and the date were also recorded. In addition, test hauls with a 500-foot seine of ¼-inch mesh (bar measure) were made to determine principally the magnitude of reproduction for each species of fish in the lake. These two sources of data indicate a very significant increase in game-fish populations in East Okoboji following the intensive rough-fish-removal program.

East Okoboji Lake is one of a chain of six lakes in Dickinson County, Iowa, that comprise what is locally known as the "Iowa Great Lakes." The lake is approximately 1,400 acres in area, and has a maximum depth of about 26 feet. The upper portion of the lake above the "narrows" is shallow, with an average depth of around 6 feet. Shores for the most part are gradually sloping; some sections are walled with glacial boulders.

Boulders also form numerous rock points and submerged reefs, especially in the lower portion of the lake. During periods of normal water level, Spirit Lake overflows into East Okoboji at the northern end of the lake. West Okoboji flows into East Okoboji at the lower end of the lake. Flowage continues from East Okoboji through Upper Gar, Minnewashta, and Lower Gar Lakes finally forming a tributary to the Little Sioux River (Fig. 1). All of the lakes in this region were formed by the Wisconsin glacier, and are of the eutrophic type.

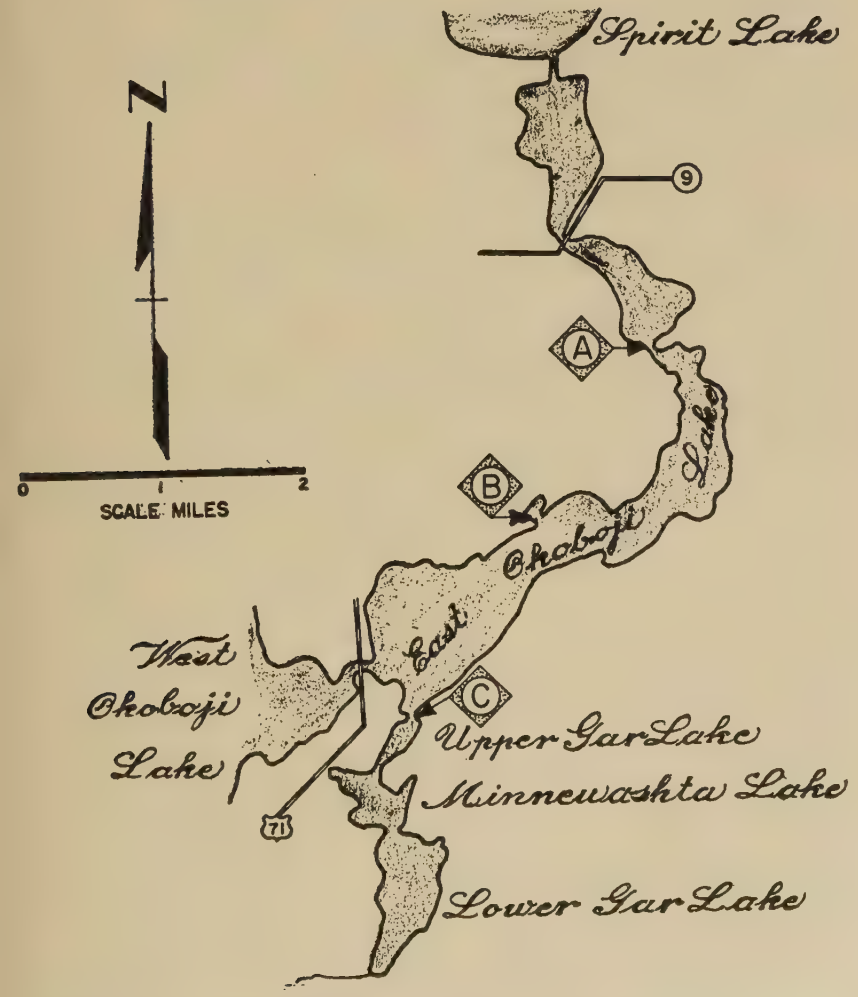

FIGURE 1.—Map of East Okoboji Lake and connecting waters. Letters indicate fish-trapping sites.

During the hot summer period the lake is subject to heavy blooms of blue-green algae, particularly *Aphanizomenon* and *Microcystis*. These growths reduce the recreational value of the lake to a considerable degree.

Black bullheads (*Ameiurus melas melas*), crappies (*Pomoxis nigromaculatus* and *P. annularis*), walleyes (*Stizostedion vitreum vitreum*), yellow perch (*Perca flavescens*), and white bass (*Morone chrysops*) provide most of the angling. Carp, buffalo and sheepshead are the principal rough fishes and large numbers are removed each year with seines and traps by the Iowa Conservation Commission's fish-management section. Some winter gill-netting by contract was permitted in past years, but insignificant numbers of rough fish were taken from the lake by this method.

The stocking of fish is confined principally to walleye fry and fingerlings from local hatchery and nursery units. Other species of game fish depend almost entirely upon natural reproduction for maintenance.

Rough-Fish-Removal Operations

The seining for rough fish in this program was confined entirely to open-water periods, principally in the spring and fall when cool water permitted safe handling of game fishes. Some hauls were made during hot weather when concentrations of rough fish were observed. Early-season seining was confined to shallow bays and likely spawning areas, whereas late-summer and fall seining covered more of the deeper portions of the main lake. Most of the hauls were made with 2,500-foot, 2½-inch-mesh (bar measure) drag seine. During the period from 1940 through 1946, seining was supplemented by pound nets at the "narrows" (A in Fig. 1). From 1947 through 1951 one or two permanent traps were used (B and C in Fig. 1).

Results of the seining, trapping and the very small amount of winter gill-netting for rough fish are recorded in Table 1 for the 12-year period 1940–1951.[1] The yearly catches of each species by each method are combined to obtain total annual production and pounds removed per acre. It is readily apparent that the years 1940–1943 were the most productive in pounds per acre of rough fish removed. During this period, on the average, 434 pounds per acre were removed, (range of 259 to 681 pounds per acre) (Fig. 2). Inasmuch as the length of seine and mesh size were similar during the 12-year period, and haul locations varied little from year to year, the catches per haul are probably a valid index of abundance (Table 2; Fig. 3). The catch of rough fish per unit effort declined significantly following the high catches of 1940. The relatively high catches of rough fish per unit effort shown in the years 1946 and 1949 are attributed to recruitment in the population of vulnerable size groups. The low catch of rough fish per unit effort in 1951 is attributed to a partial freeze-out in the spring of 1951, prior to break-up of ice cover.

Following the heavy exploitation of rough fish from 1941 to 1943 inclusive, a considerable increase in the average number of game fish per

[1] Seining prior to 1940 was on a comparatively limited scale. Data from State biennial reports indicate that less than 100 pounds per acre were removed annually for the period 1935-1939.

TABLE 1.—*Total weight (thousands of pounds) and pounds per acre of each species of rough fish removed by seines, traps, and gill nets from East Okoboji, 1940-1951*

Species	Gear	Year											
		1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
Total weight (thousands of pounds) removed													
Buffalo	Seines	216.0	420.2	480.0	262.8	28.2	49.2	59.1	75.4	24.3	13.9	0.9	4.0
	Traps	45.6	88.1	253.6	98.4	14.1	51.8	40.1	0.0	0.1	2.9	1.5	16.8
	Gillnets	0.4	0.6	1.1	.....	.....	.....	.....	.....	.....	1.6	.....	.....
	Total	262.0	508.9	734.7	361.2	42.3	101.0	99.2	75.4	24.4	18.4	2.4	20.8
Carp	Seines	22.0	65.8	153.5	71.2	24.2	81.7	25.6	22.2	4.4	25.9	42.0	22.2
	Traps	0.5	16.1	2.0	6.0	6.0	16.0	7.4	21.0	4.4	44.2	5.4	4.0
	Gillnets	10.2	9.9	2.2	.....	.....	.....	.....	.....	.....	12.8	.....	.....
	Total	32.7	91.8	157.7	77.2	30.2	97.7	33.0	43.2	8.8	82.9	47.4	26.2
Sheepshead	Seines	67.9	41.2	55.8	29.2	4.8	17.5	4.9	19.2	23.4	2.0	9.7	12.3
	Traps	0.5	4.2	5.4	1.0	0.6	0.4	0.4	0.0	0.0	0.2	T[1]	0.1
	Gillnets	0.0	0.0	0.0	.....	.....	.....	.....	.....	.....	T	.....	.....
	Total	68.4	45.4	61.2	30.2	5.4	17.9	5.3	19.2	23.4	2.2	9.7	12.4
All three	Grand Total	363.1	646.1	953.6	468.6	77.9	216.6	137.5	137.8	56.6	103.5	59.5	59.4
Weight (pounds) removed per acre													
Buffalo	All gears	187.1	363.5	524.8	258.8	30.2	72.1	70.8	53.8	17.4	13.1	1.7	14.8
Carp	All gears	23.2	65.6	112.6	55.1	21.6	69.8	23.6	30.8	6.2	59.2	33.9	18.7
Sheepshead	All gears	48.8	32.4	43.7	21.6	4.0	12.8	3.8	13.7	16.7	1.6	6.9	8.8
All species	All gears	259.1	461.5	681.1	334.7	55.6	154.7	98.2	98.3	40.3	73.9	42.5	42.3

1 Less than 50 pounds

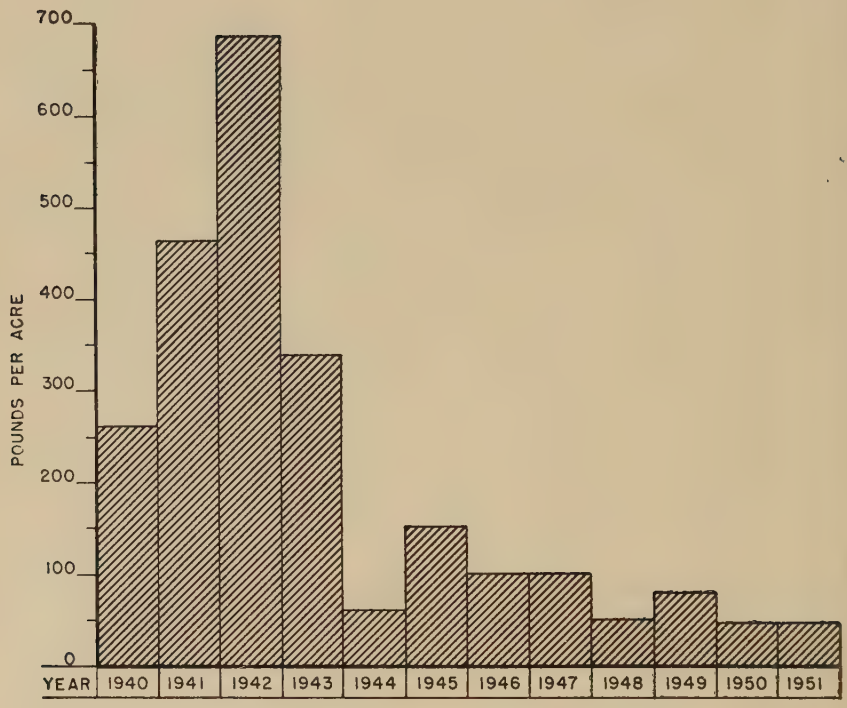

FIGURE 2.—Pounds per acre of rough fish removed from East Okoboji Lake, 1940–1951.

haul was obtained (Table 2; Fig. 4). The increase was particularly significant in the populations of yellow perch, crappie, bullhead, and bluegill. White bass and walleye increased somewhat throughout the latter part of the 12-year period. The increase in game fish is particularly evident in the grand average catch per haul starting with the year 1946. From this year until the freeze-out of 1951, a tremendous increase in game-fish populations is readily apparent. The number of pounds of game fish per haul (Table 2) of the 2,500-foot seine is an approximation obtained from sample weights.

The ratios of game fish to rough fish indicate an improved balance in the fish populations. The average ratio from 1940–1945 inclusive was 1 pound of game fish to 78 pounds of rough fish per haul, and from 1946 to 1951 inclusive the ratio was 1 to 13.

TEST SEINING

As was mentioned previously, lake-survey test hauls were started the same year as the recording of catch data by the rough fish removal crews. The data from the lake-survey catches (Table 3; Fig. 5) include the aver-

TABLE 2.—*Average catch of rough fish (pounds) and number and pounds of game fish per seine haul in East Okoboji, 1940-1951*

[Most hauls were made with a 2,500-foot, 2½-inch-mesh (bar measurement) seine]

Species	Year											
	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	[1]1951
Pounds of rough fish per haul												
Buffalo	5,142	3,964	2,652	2,412	1,409	847	2,959	1,584	1,001	994	36	167
Carp	523	469	848	653	1,211	1,409	1,180	463	1,811	850	1,116	927
Sheepshead	1,618	352	308	267	240	302	245	401	973	158	372	514
Total	7,283	4,785	3,808	3,332	2,860	2,558	4,384	2,448	2,115	3,002	2,024	1,608
Number of game fish per haul												
Northern pike	3	1	2	1	T[2]	2	4	1	2	2	3	1
Walleye	10	4	3	4	6	8	4	2	15	2	12	14
Largemouth bass	1	3	1	2	2	2	2	1	5	13	3	2
White bass	2	T	1	1	2	5	3	6	30	3	T	1
Perch	T	T	T	T	2	T	10	2	46	5	321	10
Crappies	137	41	27	67	86	46	260	1,175	1,117	33	140	10
Bluegills	2	1	2	2	4	5	10	3	55	6	244	8
Bullheads	6	3	9	7	10	13	27	60	120	363	712	16
Total	161	53	43	84	112	81	320	1,250	1,290	427	1,435	62
Pounds of game fish per haul	111	39	28	54	69	63	185	631	694	234	697	58
Number of hauls	42	106	181	109	20	58	20	48	24	14	26	26

[1] Heavy winter kill, winter of 1950-51

[2] Less than 0.5 fish per haul, any fraction greater than 0.5 was counted as 1.0

age number of young-of-the-year and older game fish and rough fish obtained per haul during the 12-year period (no survey data for 1943).

The lake-survey data (Table 3) closely parallel those of the rough-fish hauls (Table 2) in indicating the upward trend in populations of adult game fish after 1946. In addition, a striking increase in reproduction of game fish occurred through the period, 1946–1951 (Fig. 5). The average

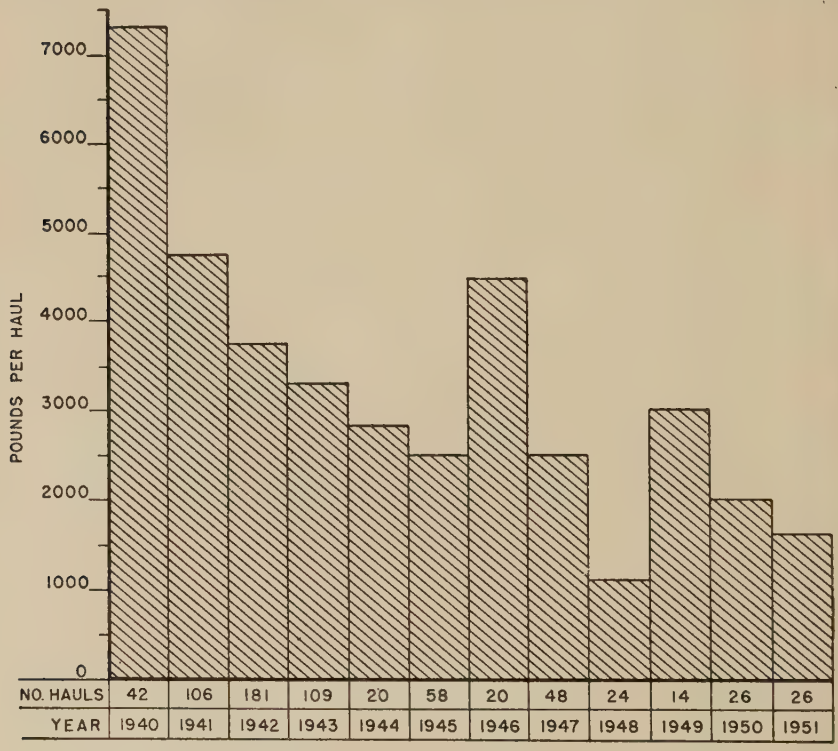

FIGURE 3.—Average catch (pounds) of rough fish per haul in East Okoboji Lake, 1940–1951.

number of young-of-the-year obtained per haul from 1940 through 1945 was only 442 fish, whereas the average number per haul from 1946 through 1951 was 8,553 fish, or roughly a 20-fold increase.

CHANGES IN VEGETATION AND QUALITY OF ANGLING

Vegetation.—Aquatic vegetation, particularly submerged plants, have returned to the lake in great abundance since 1946, especially in the northern, shallow portions, and in the littoral zones of the main lower lake. *Myriophyllum, Ceratophyllum,* and many species of *Potamogeton* (pri-

marily *richardsonii, pectinatus, zosteriformis,* and *pusillus*) have literally choked out former open-water areas. The heaviest vegetation is present in that portion of the lake north of the No. 9 highway (Fig. 1). Boat travel is difficult in this area and many cottage owners have registered complaints due to the excessive growth. Several large beds of *Vallisneria americana* have developed in the main lower lake for the first time since the early

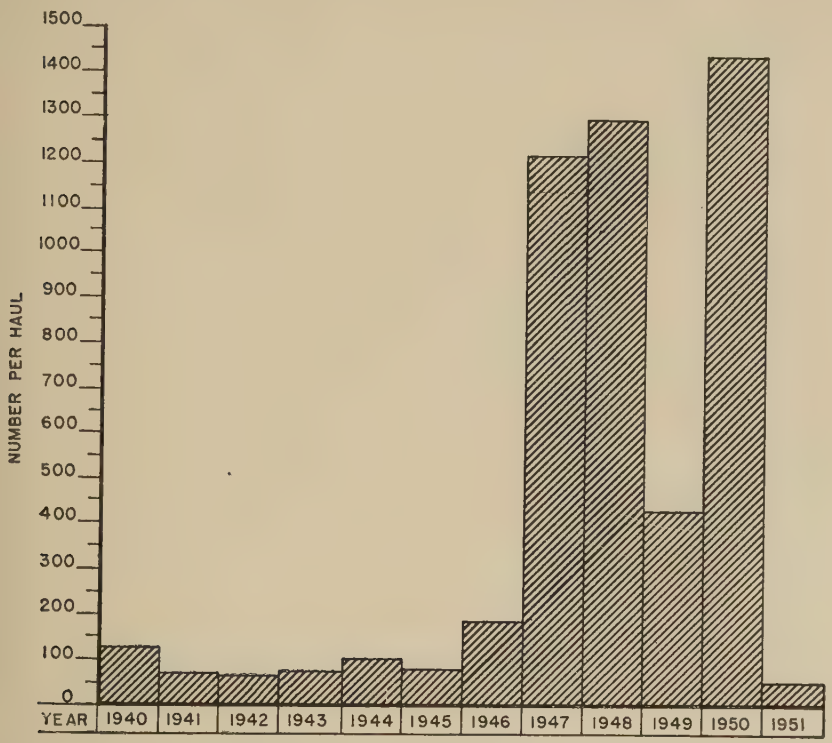

FIGURE 4.—Average number of adult game fish caught per haul in East Okoboji Lake during rough fish seining operations, 1940–1951.

1930's. The increase in vegetation following extensive rough-fish removal is similar to that observed by Moyle (1949) and Threinen (1949). Also, it has been noted that in the upper region of dense vegetation the development of blue-green algae has been limited, whereas objectionable blooms were formerly frequent. It is conceivable that the nutritive elements favoring algal growths are now utilized to better advantage by the higher plants.

Angling.—Although we have no creel-census records for East Okaboji prior to 1945, angling is generally known to have been poor for several years previous to this time. Creel-census records from 1945 to 1951 show an average catch of 1.24 fish per hour (Rose, 1951), a figure comparable to those for most of the Iowa lakes.

TABLE 3.—*Average number of young-of-the-year and older game and rough fish obtained per haul in East Okoboji, 1940-1951*

[Data from Lake Survey records; based on hauls of a 500-foot seine of ¼-inch mesh (bar measurement)]

Species	Age	Year										
		1940	1941	1942	[1]1944	1945	1946	1947	1948	1949	1950	[2]1951
Number of rough fish per haul												
Buffalo	Young	0	0	0	0	0	0	0	0	1	1	5
	Older	93	24	3	5	1	10	2	T[3]	0	5	T
Carp	Young	7	0	0	0	T	16	0	4	308	T	0
	Older	12	125	23	10	6	8	3	16	4	247	9
Sheepshead	Young	384	459	317	73	13	7	28	1	2	3	217
	Older	70	18	35	53	26	31	23	25	5	27	2
Total	Young	391	459	317	73	13	23	28	5	311	4	222
	Older	175	167	61	68	33	49	28	41	9	279	11
Number of game fish per haul												
Northern pike	Young	0	0	0	0	0	0	T	T	0	0	T
	Older	T	T	1	2	T	0	1	0	2	1	T
Walleye	Young	7	4	9	3	14	43	10	T	9	2	196
	Older	3	5	7	2	2	4	19	14	6	16	T
Largemouth bass	Young	0	0	1	39	0	2	8	34	101	10	0
	Older	1	T	T	1	1	T	1	3	6	9	T
White bass	Young	1	T	0	779	36	2	40	3	7	6	3
	Older	T	1	1	1	2	13	16	17	T	10	T
Perch	Young	20	14	83	265	101	410	2,614	394	8,797	89	5,383
	Older	14	31	17	5	6	7	65	36	376	211	89
Crappies	Young	61	55	66	544	60	3,173	1,393	452	433	50	10
	Older	14	15	11	5	38	27	47	56	13	40	7
Bluegills	Young	T	T	0	8	13	2,000	1,565	1,613	4,680	2,014	2
	Older	4	2	2	4	21	21	48	54	68	110	3
Bullheads	Young	0	0	0	8	8	400	15	44	11,539	3,751	T
	Older	157	24	26	4	25	37	40	10	1	241	18
Total	Young	89	73	159	1,646	241	6,030	5,645	2,558	25,566	5,922	5,594
	Older	193	78	65	24	94	109	237	190	472	638	100
Number of hauls		18	9	9	9	9	8	9	7	4	4	5

[1] No records for 1943
[2] Heavy winter kill, winter of 1950-51
[3] Less than 0.5 fish per haul, any fraction greater than 0.5 was counted as 1.0

Removal of Rough Fish as a Management Technique

In an evaluation of these data, we wish to point out certain factors that appear important, and at the same time reserve positive judgment concerning any cause-and-effect relationship. That an increase in game fish did occur in measureable quantities in East Okoboji following some of the most intensive rough-fish-removal efforts the State of Iowa has ever attempted appears to be significant.

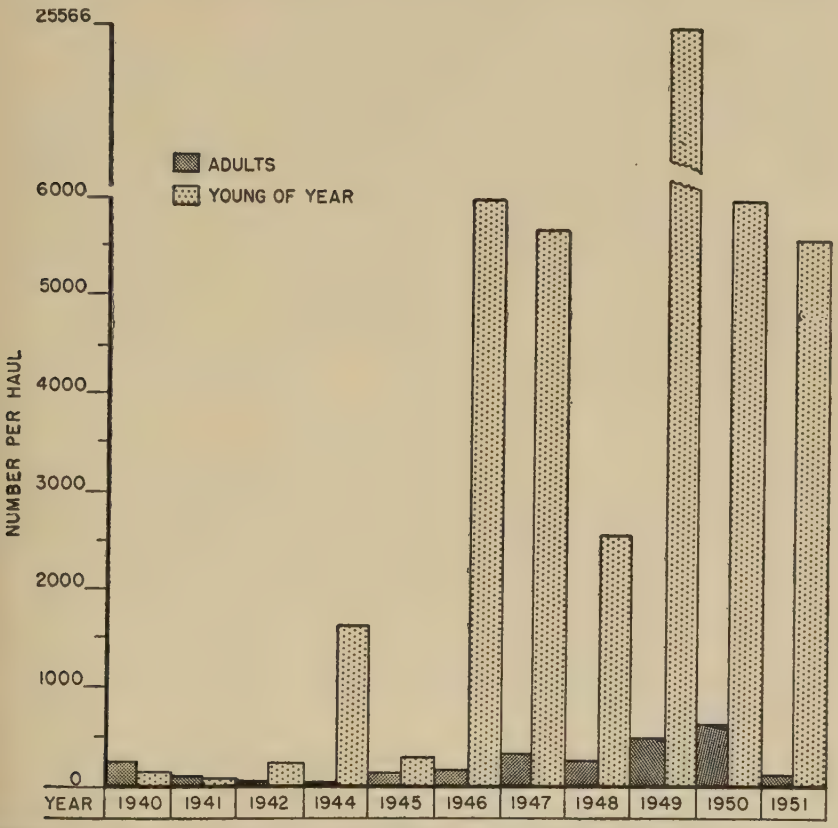

Figure 5.—Average number of young-of-the-year and older game fish obtained per haul in East Okoboji, 1940–1951.

Had this project been set up orginally as an experiment, other factors such as age composition, growth rates, condition factors, bottom fauna, and vegetation would have been studied in sufficient detail, thereby adding much to our understanding of the quantitative data given here. Inasmuch as bottom samples, scale samples, and records of weights and lengths of fish were not taken in lake-survey work prior to about 1945, our data for the later years are of little value in this comparison.

The Iowa Conservation Commission's policy on rough-fish removal has been based for many years on the theory that these fish are detrimental to and competitive with the more desirable species of fish. Rough-fish control has been vigorously carried on year after year in several Iowa lakes. In these lakes game-fish populations have been large and angling has in general been good. On the other hand, in several lakes with large populations of rough fish that have not been seined so intensively, game-fish populations have remained at consistantly low levels.

Observations in Minnesota by Johnson (1949), indicated that if carp could be completely eradicated from a lake, a replacement by game fish might be expected at the rate of from 15 to 20 pounds for every 100 pounds of carp removed. If this replacement rate applies in Iowa, a vast improvement in game-fish populations could be expected to result from rough-fish removal in lakes whose rough-fish populations were in the neighborhood of 500 pounds per acre or more. Ricker and Gottschalk (1941) reported increases in game fishes and significant improvements in environmental conditions in Bass Lake, Indiana, following extensive removal of coarse fish.

It would appear then that where carrying capacities for fish are high, as in the lakes of northern Iowa, and where rough fish are strongly dominant, reduction must be extensive and continual in order to effect significant increases in game-fish populations.

Acknowledgments

We wish to thank the Superintendent of Rough Fish Removal of the Iowa Conservation Commission, Mr. Charles O'Farrel, for making available his records and for his help in analysis of data. We are grateful also for the encouragement and aid in the preparation of this paper from Dr. Kenneth Carlander, Iowa State College, and E. B. Speaker, Superintendent of Biology, Iowa State Conservation Commission.

Literature Cited

Johnson, Raymond E.
1949. Maintenance of natural population balance. Proc. 38th Conv. Int. Assoc. Game, Fish and Cons. Comm. (1948), pp. 35–42.

Moyle, John B.
1949. Fish population concepts and management of Minnesota lakes for sport fishing. Trans. 14th N. Am. Wildlife Conf., pp. 283–284.

Ricker, William E., and John Gottschalk
1941. An experiment in removing coarse fish from a lake. Trans. Am. Fish. Soc., Vol. 70 (1940), pp. 382–390.

Rose, Earl T.
1951. The 1951 Iowa creel census. Quart. Biol. Rep., April, May and June 1951, Vol. 3, No. 2. Iowa State Cons. Comm. pp. 1–12. [Mimeographed]

Threinen, C. W.
1949. The effect of carp upon the normal aquatic habitat. Wis. Cons. Dept., Fish. Biol. Sec., Invest. Rep. No. 709, pp. 1–21. [Mimeographed]

THEORETICAL YIELDS AT VARIOUS RATES OF NATURAL AND FISHING MORTALITY IN STABILIZED FISHERIES [1]

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Abstract

In theoretical, stabilized fish populations it is shown that maximum yield in weight depends not only on the rates of natural and fishing mortality but also on the nature of growth in weight. Families of yield curves at various combinations of natural and fishing mortality rates are presented for three growth types with point of inflection (A) early in life, (B) about mid-life, and (C) late in life. Maxima appear in all three types but at progressively lower natural mortality rates. The curves are of limited practical value because of the many assumptions which are involved.

Introduction

Series of curves depicting yield (weight of catch) for fisheries which have been stabilized at various levels of natural and fishing mortality have been published by Baranoff (1918, Fig. 10), Thompson and Bell (1934, Fig. 9), and Ricker (1944, Fig. 1).

Thompson and Bell's mathematical model was that of a Type IB fishery (Ricker, 1944) in which there was no recruitment during the fishing season. Growth in weight was considered to be exponential, an assumption which seemed applicable over a limited range of ages (IV to XI) for halibut of the commercial catch. The yields for smaller rates of natural mortality ($n = 0.05$ and 0.10) decreased rapidly with increase in rate of fishing mortality (m), and showed no maxima; for larger rates of natural mortality ($n = 0.21$ to 0.40) they increased with increase in rate of fishing mortality; and for an intermediate rate ($n = 0.18$) the yield tended to remain constant with increase in rate of fishing mortality.

Baranoff's paper, in Russian, remained unknown in the Western Hemisphere until several years after Thompson and Bell's publication. Ricker (1944) pointed out certain differences between Baranoff's figure and that of Thompson and Bell, "notably . . . that Baranoff's shows a gradual ascent to a maximum catch, with increasing fishing mortality, and later a drop —but only when the natural mortality rate [n] is between about 0.05 and 0.20". To investigate the reason for this difference, Ricker calculated the yields in a mathematical model similar to that used by Baranoff, namely, a Type IIA fishery, in which recruitment occurs at a uniform rate through-

[1] Contribution No. 30, Hawaii Marine Laboratory.

out the year. However, with Thompson and Bell, he allowed growth in weight to proceed exponentially. In general, his curves were similar to those of Thompson and Bell in that no maxima appeared at the lower natural mortality rates. He concluded that the difference between these curves and those of Baranoff's arises from the type of growth rather than from the nature of recruitment, for Baranoff, who was working with North Sea plaice, assumed linear increase in length, with weight increasing as the cube of the length.

The curves of yield are of sufficient theoretical interest to warrant further investigation of their shape with types of growth other than those used by previous workers. Although it is convenient mathematically to assume that growth proceeds over the entire life span exponentially, it is not realistic. It has been shown in many species of fish and other animals that the growth curve is usually S-shaped, with the absolute growth rate accelerating up to the point of inflection and thereafter decelerating. Neglect of the decelerating phase of growth would disproportionately magnify the yields at the lower mortality rates, for at these lower rates the numbers of older and larger fish in both the population and catch are relatively high.

It is the purpose of this paper to present a series of curves depicting the yields for fisheries stabilized at various rates of natural and fishing mortality, for each of three types of S-shaped growth curve: Type A, point of inflection early in life; Type B, point of inflection about midlife; and Type C, point of inflection late in life.

For the mathematical model a fishery of Type IB, similar to that used by Thompson and Bell (1934), has been used. Trial calculations with a fishery of Type IIA, similar to that used by both Baranoff and Ricker, showed that maxima occurred at the same rates of fishing mortality as those for a Type IB fishery, and that the curves differed only in the magnitude of yield.

Method of Calculation

Three curves representing growth Types A, B, and C (see above) were drawn freehand on squared paper to cover a range of 0 to 100 weight units and 0 to 18 years of age. The average weight at each age was then read to the nearest whole weight unit from the graph. All fish above 18 years of age were assumed to have the maximum weight of 100 units. The average weights at each age are included in Table 1.

For each fishery it was assumed that 1,000 recruits entered the fishable stock each year in advance of the fishing season. The resultant population was subjected to instantaneous rates of natural mortality ranging from $q = 0.05, 0.10, 0.20 \ldots$,up to 1.0, each in combination with instantaneous rates of fishing mortality ranging from $p = 0.05, 0.10, 0.20, \ldots$ up to 1.2.

For each combination of natural and fishing mortality rate (*e.g.*, $q = 0.10$ and $p = 0.20$) a total instantaneous rate of mortality, i (*e.g.*,

0.30), was obtained. By means of the tables published by Ricker (1948), the annual rate of mortality, $a = 1 - e^{-i}$ (*e.g.*, 0.2592), the survival rate, $s = 1 - a$ (*e.g.*, 0.7408), and the fraction, a/i (*e.g.*, 0.8639), were determined. The rate of exploitation, $u = ap/i$ (*e.g.*, $0.8639 \times 0.20 = 0.17278$), was then calculated.

The initial population number at each age was obtained according to successive terms of the progression: $1000s$, $1000s^2$, etc. The sum of these numbers gave the total initial population. This value was checked against $N = 1000/a$. If numbers occurred beyond the age of 18 years (to the second decimal place), the excess was determined as the difference between the total up to and including the eighteenth year and the calculated total, N, and entered as the number at the age of 18+. The initial number of fish at each age, multiplied by u, gave the number of fish in the catch at each age. This figure, multiplied by the average weight at each age, and summed, gave the yield in weight for the stabilized population. This process was repeated for each combination of p and q. The work sheet for one combination of rates ($q = 0.10$; $p = 0.20$) is shown in Table 1.

TABLE 1.—*Yields at* q=*0.10 and* p=*0.20 for three growth types*
[N is initial population number, C is catch number, G_a, G_b, and G_c are average weights at each age for growth types, A, B, and C, and W_a, W_b, and W_c are yields in weight for growth types A, B, and C]

Age	N	C	G_a	W_a	G_b	W_b	G_c	W_c
1	1000.00	172.78	2	345.56	2	345.56	2	345.56
2	740.80	128.00	8	1024.00	4	512.00	4	512.00
3	548.78	94.82	30	2844.60	7	663.74	6	568.92
4	406.54	70.24	50	3512.00	12	842.88	8	561.92
5	301.16	52.03	63	3277.89	17	884.51	10	520.30
6	223.10	38.55	72	2775.60	25	963.75	12	462.60
7	165.27	28.56	79	2256.24	32	913.92	14	399.84
8	122.43	21.15	85	1797.75	42	888.30	17	359.55
9	90.70	15.67	91	1425.97	58	908.26	22	344.74
10	67.19	11.61	94	1091.34	73	847.53	26	301.86
11	49.77	8.60	97	834.20	82	705.20	32	275.20
12	36.87	6.37	98	624.26	88	560.56	43	273.91
13	27.31	4.72	98	462.56	93	438.96	62	292.64
14	20.23	3.50	99	346.50	95	332.50	85	297.50
15	14.99	2.59	99	256.41	97	251.23	94	243.46
16	11.10	1.92	99	190.08	98	188.16	97	186.24
17	8.22	1.42	100	142.00	99	140.58	99	140.58
18	6.09	1.05	100	105.00	100	105.00	100	105.00
18+	17.47	3.02	100	302.00	100	302.00	100	302.00
Total	3858.02	.....	...	23613.96	...	10794.64	....	6493.82

An alternate approach to the calculation of the various yields would be to choose three curves of Types A, B, and C which followed, say, the logistic or Gompertz equation, and attempt to combine the formulae of growth with those of mortality. The present method is simpler mathematically, although it involves considerable labor in calculation. For the bulk of the computations I am indebted to the following University of Hawaii students: Donald Strasburg, Michio Takata, Iwao Adachi, Daniel Kop, and Howard Yoshida. I am also indebted to Dr. W. E. Ricker, Fish-

eries Research Board of Canada, Nanaimo, B. C., for helpful suggestions arising from his review of the manuscript.

Relation of Growth Type to Yield

The yields are plotted in Figures 1, 2, and 3, and are joined by continuous curves, fitted by eye. Inserted in each figure are curves showing the assumed growth type, plotted on both an arithmetic scale (solid line) and a logarithmic scale (broken line) for the weight variate.

For a given combination of natural and fishing mortality rates, in general the yield is large for Type A growth, smaller for Type B, and still smaller for Type C—a result which would be anticipated from the shape of the growth curves. Thus, for $q = 0.10$ and $p = 0.20$, the yields for each growth type are respectively 23,614, 10,795, and 6,494 weight units (Table 1). However, this trend has no general significance, since average weight at a given age will differ from species to species regardless of growth type.

Each series approaches the same limiting value (2,000 weight units) as p approaches infinity. For higher natural mortality rates this limiting value represents maximum yield. However, it does not represent maximum *sustained* yield, for if all the fish were caught as soon as recruited, no spawners would be left and the assumption of constant recruitment, on which these curves are based, could no longer hold. As Thompson and Bell (1934) have pointed out, in such fisheries where the gain from growth is less than the loss from natural mortality, maximum sustained yield will be obtained with an intensive fishery (a high value of p), but the intensity should be only "as great as is consistent with maintenance of the supply of young. . . "

For the lower natural mortality rates, maximum yields (greater than 2,000 weight units) occur in all three series of curves. As in Baranoff's figure, the modes become smaller in absolute value and move to the right (*i.e.*, they occur at higher values of p) as natural mortality rate becomes greater. But whereas in Baranoff's figure, maxima were not encountered at natural mortality rates greater than $q = 0.30$ (for his Fig. 10, $q = 5k_0$), in ours they persist at all natural mortality rates up to $q = 0.9$ for Type A growth, $q = 0.5$ for Type B growth, and $q = 0.3$ for Type C growth. However, the maxima become progressively less pronounced as q approaches these values. In such fisheries, where the gain from growth exceeds the loss from natural mortality, maximum yield will be obtained with a fishery of relatively low intensity, the optimum rate of fishing, p, being indicated by the position of the mode. This production will, of course, be maximum *sustained* yield if the accumulated stock at this level of fishing mortality is sufficient to maintain the supply of new recruits.

The curves are of interest chiefly in demonstrating that the occurrence of maxima depends on growth type as well as on mortality rates. They are of limited practical value. Growth Type A is approximated in the Pacific herring *Clupea pallasi* (Tester, 1948, Fig. 6). Assuming a high natural

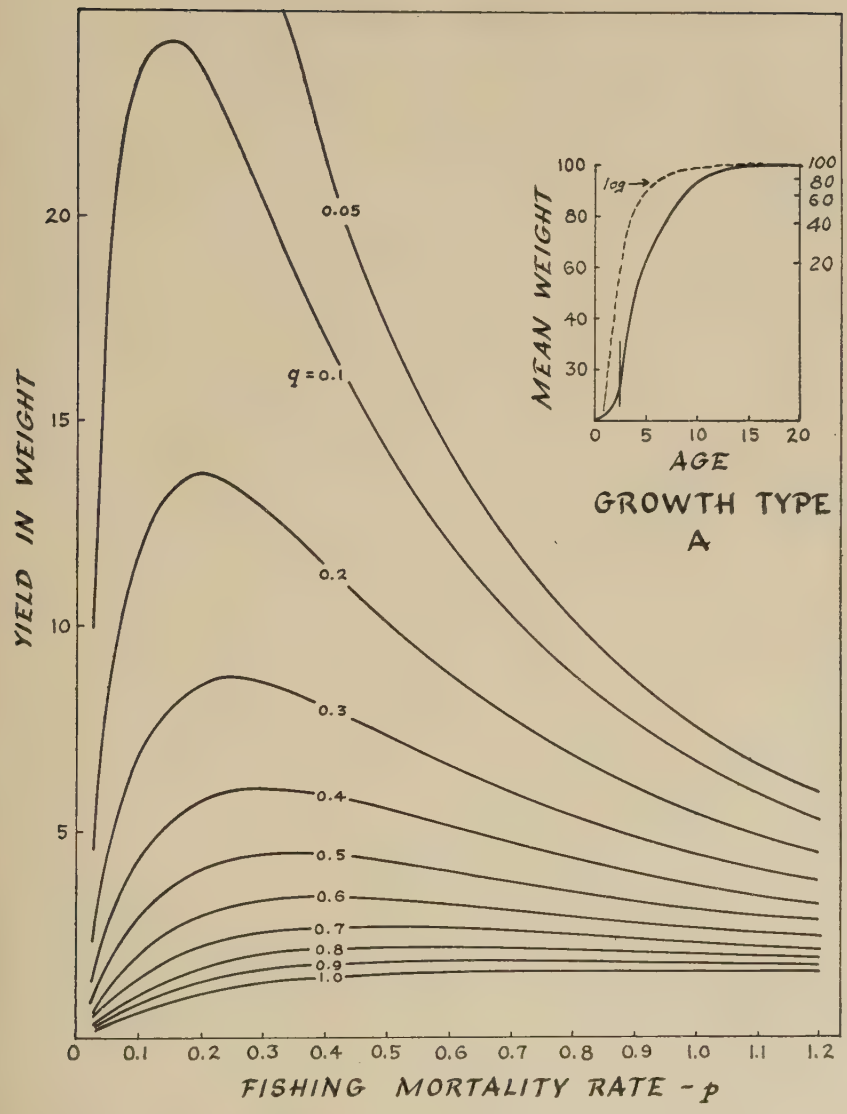

FIGURE 1.—Yields, in thousands of weight units, for various instantaneous fishing mortality rates (p) in combination with various instantaneous natural mortality rates (q), with Type A growth (see insert). The yields at each natural mortality rate have been joined with a continuous curved line.

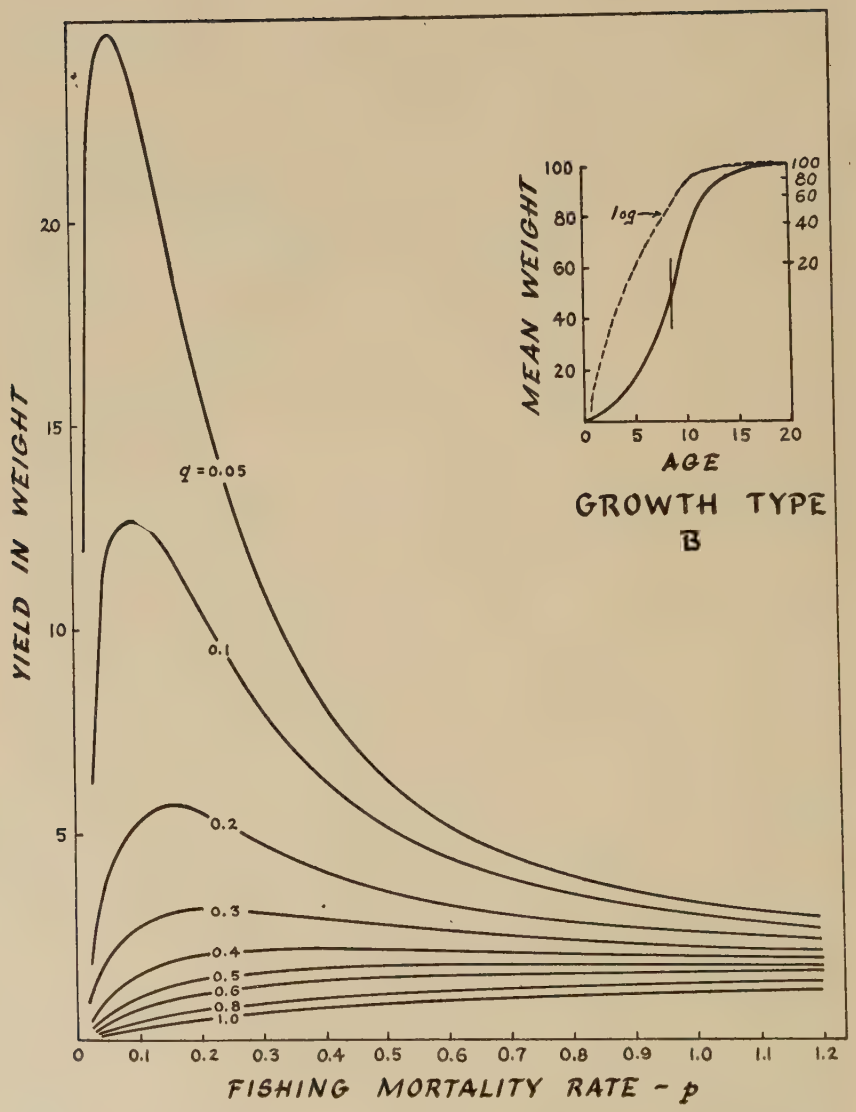

FIGURE 2.—Yields, in thousands of weight units, for various instantaneous fishing mortality rates (p) in combination with various instantaneous natural mortality rates (q), with Type B growth (see insert). The yields at each natural mortality rate have been joined with a continuous curved line.

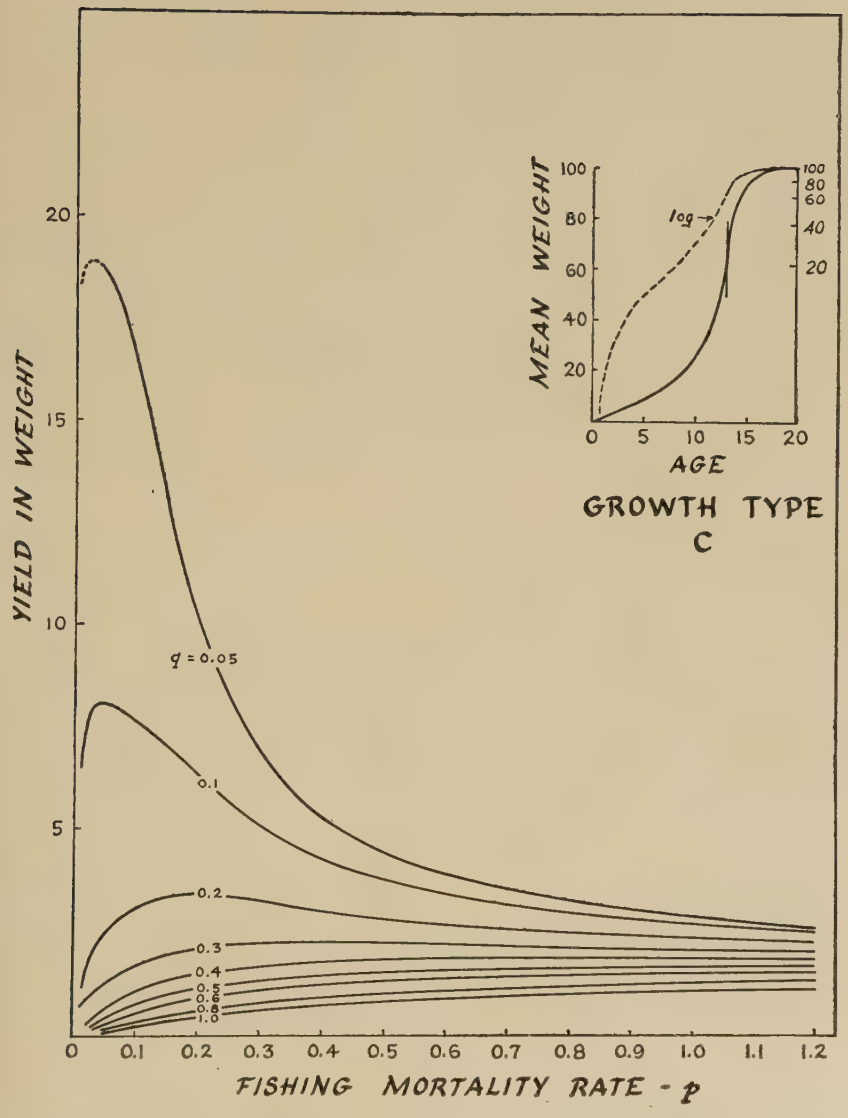

FIGURE 3.—Yields, in thousands of weight units, for various instantaneous fishing mortality rates (p) in combination with various instantaneous natural mortality rates (q), with Type C growth (see insert). The yields at each natural mortality rate have joined with a continuous curved line.

mortality rate ($n = 0.5$ to 0.6; $q = 0.7$ to 0.9), it might be deduced that yield varies only slightly over the expected range of fishing mortality rates ($p = 0.3$ to 0.8) and that the attainment of maximum sustained yield will depend primarily on maintaining a sufficient supply of spawners to produce continued and approximately constant recruitment—beyond Point X in Fig. 7, (Tester, 1948). Growth Type C may be approximated in the Pacific halibut *Hippoglossus stenolepis*, (Thompson and Bell, 1934, Fig. 8). Assuming a low natural mortality rate (of the order $n = q = 0.1$ to 0.2) it might be deduced that maximum yield will be attained at a low rate of fishing mortality ($p = 0.1$ to 0.2), at which value there should be an adequate spawning stock to assure a continued supply of young. However, even with reliable estimates of natural mortality and growth rates, conclusions based on theoretical curves of yield should be accepted with caution in view of the many other assumptions which are involved and the complications which may arise from fishery-independent changes in population abundance (Burkenroad, 1951).

Literature Cited

Baranoff, Th. I.
1918. On the question of the biological basis of fisheries. Nauchnyi issledovatelskii iktiologisheskii Institut, Izvestiia, Vol. 1, No. 1 (1916), pp. 81–128. [Translated by W. E. Ricker, Bloomington, Indiana, January 1945]

Burkenroad, M. D.
1951. Some principles of marine fishery biology. Pub. Inst. Marine Sci. (Texas), Vol. II, No. 1, pp. 177–212.

Ricker, W. E.
1944. Further notes on fishing mortality and effort. Copea, 1944, No. 1, pp. 23–44.
1948. Methods of estimating vital statistics of fish populations. Indiana Univ. Pub., Sci. Ser. No. 15, 101 pp.

Tester, A. L.
1948. The efficacy of catch limitations in regulating the British Columbia herring fishery. Trans. Roy. Soc. Canada, Vol. 42, Ser. III, Sec. 5, pp. 135–163.

Thompson, W. F. and F. H. Bell
1934. Biological statistics of the Pacific halibut fishery, (2) Effect of changes in intensity upon total yield and yield per unit of gear. Rep. Internat. Fish. Comm. No. 8, 49 pp.

MOVEMENT OF PARASITIC-PHASE SEA LAMPREYS IN LAKES HURON AND MICHIGAN

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Abstract

A program of tagging was carried out in the waters of northern Lake Huron during the fall and winter of 1951–52 in order to supplement the small amount of information available on the movement of sea lampreys during their parasitic phase. A total of 219 parasitic-phase sea lampreys were tagged and released at three localities. Of this number 38 or 17.2 percent were recovered. One tag was recovered near North Manitou Island, Lake Michigan. The remaining 37 were taken in Lake Huron or in streams tributary to that lake. The dispersal of tagged lampreys throughout Lake Huron was wide. Five marked individuals were taken in the southern part of the lake over 150 miles from the point of tagging; 4 of these 5 were captured in Canadian waters. The marked lampreys exhibited no distinct pattern of migration other than a tendency toward a general southeasterly movement in Lake Huron.

Introduction

A knowledge of the movements of the sea lamprey, *Petromyzon marinus,* during its parasitic phase and spawning migration is essential to the framing of an effective program for the control of that species. Obviously if lampreys disperse themselves freely throughout an entire lake, control programs must be set up on a lake-wide basis. To obtain information on the movements of parasitic phase sea lampreys tagging experiments were carried out in the spring of 1950 and during the fall and winter of 1951–1952. The earlier of the two experiments, reported by Applegate and Smith (1951), demonstrated that the sea lamprey lacks a true homing instinct since individuals of a blocked spawning run returned to the lake and entered other streams.

The 1951–52 experiment, small-scale though it was, has yielded information on movements of sea lampreys during their period of active feeding of such significance that it appears desirable to report the findings at this time. Similar experiments in other areas are planned for the fall of 1952.

Materials and Methods

A total of 219 parasitic-phase sea lampreys were tagged and released at the following places (see Fig. 1) between September 14, 1951 and March 11, 1952: 190 in the Cheboygan area (107 in the turning basin

of the Cheboygan River; 78 in Duncan Bay; 5 in the Straits of Mackinaw about 4 miles west of Cheboygan); 24 in Hammond Bay; 5 on the east shore of Drummond Island.[1] The lengths of the lampreys ranged from 12.4 to 20.9 inches and averaged 16.7 inches.

FIGURE 1.—Chart of Lake Huron, except southern Georgian Bay, and northeastern Lake Michigan showing tagging localities (triangles) and points of recovery (dots) for all sea lampreys retaken outside the tagging areas. All dots indicate recovery of single individuals except in the Ocqueoc River (3 taken).

Of the sea lampreys tagged, 91 were taken by commercial type shallow trap nets and 128 by experimental nylon gill nets, specially constructed for capturing lampreys. The lampreys from the trap nets were captured incidentally in operations carried out in a sampling of the fish population of

[1] We wish to acknowledge the assistance of Vernon Seaman, Master of the Fish and Wildlife Service research vessel "Cisco" in the tagging operations.

the areas and to obtain fish for use in laboratory studies on the sea lamprey's feeding habits. Of the trap nets fished, only the net with 1-inch mesh, extension measure, in the lifting pot was efficient in taking lampreys. Most of the lampreys escaped from the larger meshed nets (meshes up to 3 inches) as they were lifted. The mesh sizes of the gill nets were 1, 1½, and 2 inches; all were hung on the one-half or the two-thirds basis.[2] Some of the nets were reefed[3] in an attempt to increase their efficiency.

To avoid the tagging of sea lampreys that had been injured in the nets all individuals were held in a live box until the next lifting day and then only the apparently unharmed individuals were tagged. The marked lampreys were released at a sufficient distance from the nets to minimize the possibility of immediate recapture in the same nets.

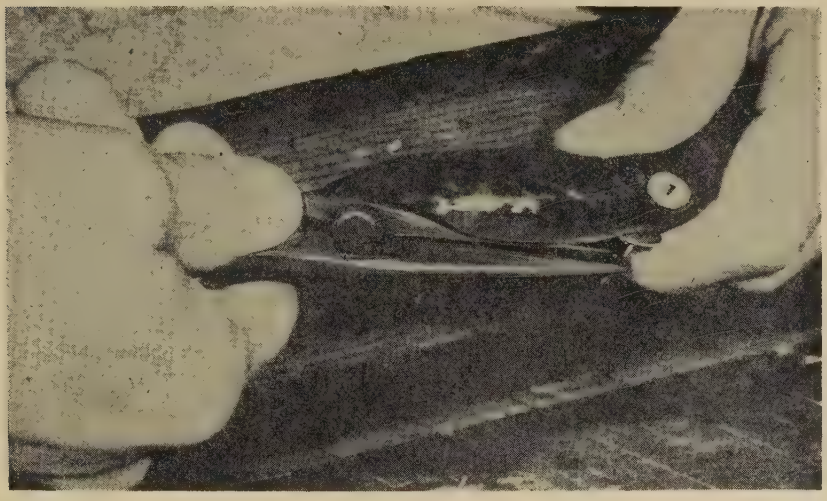

FIGURE 2.—Sea lamprey being tagged with a Peterson-type mark.

All specimens were tagged with numbered Peterson-type tags, of ⅜-inch diameter (Fig 2). One disc was red and the other was white. The discs were applied with 1¾-inch nickel wire pins through the dorsal musculature just anterior to the first dorsal fin. Peterson-type tags were used for three reasons: the white and red discs are easily visible; recapture is facilitated by the ready fouling of the discs and pins in commercial gill nets; lampreys appear to suffer no adverse effects from this type of tag (Applegate and Smith, 1951).

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[2] One-half basis—2 feet of webbing, meshes flat, per foot of maitre line; two-thirds basis—three feet of webbing per foot of line.

[3] A gill net is reefed by connecting the top and bottom lines at intervals by cords shorter than the depth of the net as hung. In this fishing 4-foot reefing lines were used on 6-foot nets.

Rate and Locality of Recapture

Of the 219 individuals tagged, 38 or 17.2 percent were recovered. Twenty-two of the lampreys were recaptured in the collectors' nets, 11 were taken by commercial fishermen, 2 were recovered in lamprey weirs (one in the Ocqueoc River, a tributary of Hammond Bay, and one in the Saugeen River in Canada), 2 were taken during electric shocking operations in the Ocqueoc River, and 1 was captured by a smelt dipper (Table 1). The 2 lampreys captured with the electric shocker no longer carried tags but had a prominent V-shaped scar in the area in which the tag had been placed. Because of the loss of the tags it was impossible to determine where and when they were released.

Thirty-five of the 36 recoveries for which the tagging locality was known had been tagged in the Cheboygan area and one had been tagged at Hammond Bay. No recoveries were made of the 5 tagged at Drummond Island.

The drawing of any precise conclusions as to the pattern of movement of sea lampreys from the data available is obviously impossible. First, the number of recoveries was too small. Second, we are not in position to evaluate the pattern of recovery in relation to the opportunity for recapture. Detailed records of fishing activity are available for all State of Michigan waters of the Great Lakes but even if more tagged lampreys had been taken by commercial operators any use of those records would have been handicapped by lack of knowledge of the degree of vulnerability of the lamprey to the different types of commercial gear.

To illustrate the significance of opportunity for recapture—the fact that 25 of 35 sea lampreys recaptured from the 190 tagged in the Cheboygan area were retaken locally might, at first thought, be taken as proof that only a small percentage of the local population moved away from that region. However, 22 of the 25 local recoveries were from our own small-mesh gill nets—gear peculiarly well adapted to the capture of sea lampreys. If these 22 individuals were excluded, we should have the figures of 3 local recaptures (2 from commercial gear and 1 by a sportsman dipping smelt from the Cheboygan River) as against 10 from other areas, and thus might lean toward the opposite conclusion that most of the lampreys tagged near Cheboygan had later deserted those waters.

Even though interpretations of the data of Table 1 must be made with considerable caution, certain significant points do appear. Most important is the fact that 4 of the 16 recoveries not made in our own nets were from Canadian waters at distances of approximately 150 to 209 miles from the points of tagging. This situation brings out forceably that the problem of controlling the sea lamprey in Lake Huron is international.[4]

It may be significant also that only one sea lamprey was recovered from Lake Michigan despite the free access to that water through the Straits of Mackinaw. Whether from pressure of local competition, from a ten-

[4] The same conclusion almost certainly would hold for Lake Superior.

TABLE 1.—*Locality and date of tagging and place and date of recovery of marked sea lampreys, and distance from point of tagging*

Date tagged	Point of release	Date recovered	Method and place of recovery	Distance (miles)	Days out
Oct. 4, 1951	Cheboygan River	Nov. 9, 1951	Attached to fish in gill net, 20 miles NE of Thunder Bay Light	76	36
do. 4, 1951	do.	Dec. 8, 1951	Commercial net, 1 mile N of Rabbit Back Pt.	23	65
do. 14, 1951	do.	Nov. 14, 1951	Attached to fish in gill net, 6 miles N of St. Ignace	23	31
do. 14, 1951	do.	Jan. 21, 1952	Chub gill net, 3 miles ESE of North Manitou Island	93	100
do. 20, 1951	do.	Oct. 31, 1951	Chub gill net, off Presque Isle Harbor	69	11
Nov. 20, 1951	Straits of Mackinac	May 20, 1952	Commercial net, 10 miles NE of Grindstone City	146	181
Jan. 8, 1952	Duncan Bay	Jan. 24, 1952	Experimental gill net, Cheboygan River	3	16
do. 8, 1952	do.	July 1, 1952	Commercial net 4 miles S of Bayfield, Ontario	209	173
do. 8, 1952	do.	Feb. 15, 1952	Experimental gill net, Duncan Bay	0	38
do. 9, 1952	do.	Apr. 10, 1952	Attached to fish in gill net, 3 miles N of Bayfield, Ontario	203	91
do. 15, 1952	Hammond Bay	Apr. 12, 1952	Commercial gill net, off Goderich, Ontario	192	87
do. 21, 1952	Cheboygan River	Feb. 22, 1952	Experimental gill net, Cheboygan River	0	32
do. 21, 1952	do.	May 7, 1952	Lamprey weir, Saugeen River, Ontario	150	105
do. 21, 1952	do.	Feb. 15, 1952	Experimental gill net, Cheboygan River	0	25
do. 21, 1952	do.	Feb. 18, 1952	Experimental gill net, Cheboygan River	0	28
do. 24, 1952	do.	Feb. 1, 1952	Experimental gill net, Cheboygan River	0	8
do. 24, 1952	do.	Jan. 26, 1952	Experimental gill net, Cheboygan River	0	2
do. 24, 1952	do.	Feb. 8, 1952	Experimental gill net, Cheboygan River	0	15
do. 25, 1952	Duncan Bay	Feb. 15, 1952	Experimental gill net, Cheboygan River	3	21
do. 25, 1952	do. [1]	Feb. 8, 1952	Experimental gill net, Duncan Bay	0	14
		Mar. 5, 1952	Experimental gill net, Duncan Bay	0	35
do. 25, 1952	do.	Feb. 6, 1952	Experimental gill net, Duncan Bay	0	12
do. 26, 1952	Cheboygan River	Feb. 1, 1952	Experimental gill net, Cheboygan River	0	6
do. 29, 1952	Duncan Bay	Feb. 23, 1952	Perch gill net, Straits of Mackinac	10	25
Feb. 6, 1952	Cheboygan River	Feb. 8, 1952	Experimental gill net, Cheboygan River	0	2
do. 6, 1952	do.	Feb. 8, 1952	Experimental gill net, Cheboygan River	0	2
do. 6, 1952	do.	Feb. 8, 1952	Experimental gill net, Cheboygan River	0	2
do. 6, 1952	do.	Feb. 8, 1952	Experimental gill net, Cheboygan River	0	2
do. 6, 1952	Duncan Bay[1]	Feb. 25, 1952	Experimental gill net, Duncan Bay	0	19
		Feb. 27, 1952	Experimental gill net, Duncan Bay	0	2
do. 6, 1952	do.	Feb. 11, 1952	Experimental gill net, Duncan Bay	0	5
do. 8, 1952	do.	Mar. 17, 1952	Commercial gill net, Straits of Mackinac	8	37
do. 11, 1952	Cheboygan River	Feb. 22, 1952	Experimental gill net, Cheboygan River	0	11
do. 11, 1952	Duncan Bay	Apr. 21, 1952	Smelt dip net, Cheboygan River	4	69
do. 13, 1952	do.	Feb. 25, 1952	Experimental gill net, Duncan Bay	0	12
do. 22, 1952	do.	Feb. 25, 1952	Experimental gill net, Duncan Bay	0	3
do. 22, 1952	do.	Feb. 25, 1952	Experimental gill net, Duncan Bay	0	3
do. 22, 1952	Cheboygan River	May 14, 1952	Lamprey weir, Ocqueoc River	26	81
Unknown	Unknown	May 27, 1952	Electric shocker, Ocqueoc Falls	...	...
Unknown	Unknown	June 2, 1952	Electric shocker, Ocqueoc Falls	...	...

[1] Recovered twice

dency to follow the general direction of water movement, or for some other reason most of the tagged lampreys that did leave the locality of marking appear to have moved to the east and south of the point of marking.

A final item of possible significance is the fact that all but one recovery from localities at a distance from the point of tagging were from lampreys marked earlier than January 24. To be sure, time available for travel and the opportunity for recapture (commercial fishing activities normally are light in late winter and early spring) doubtless played a role in this relationship. The possibility is suggested also that lampreys captured before January 24 were feeding actively and that feeding and a tendency to move about may be correlated. Sea lampreys that were being reared in aquaria in the Hammond Bay Fishery Laboratory during the 1951–52 season exhibited a sharply reduced rate of feeding near the end of January.

Literature Cited

Applegate, Vernon C., and Bernard R. Smith
1951. Movement and dispersion of a blocked spawning run of sea lampreys in the Great Lakes. Trans. 16th N. Am. Wildlife Conf., pp. 243–251.

A MORE COMPREHENSIVE DESCRIPTION OF *BACTERIUM SALMONICIDA*

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ABSTRACT

The purpose of this study was to establish a set of descriptive data which could be used as a reference or a standard in the identification of *Bacterium salmonicida*, the cause of furunculosis in fish. Since a complete description of *B. salmonicida* was not available, bacteriologists were not in a position to identify this microorganism in a manner which would meet the rigorous requirements of present-day bacteriology.

Ten strains of *B. salmonicida* were employed in these studies. A detailed description is presented which includes the morphological, cultural, and physiological characteristics of *B. salmonicida*. In addition, various factors such as oxygen, pH, temperature, and composition of media are discussed in terms of their influence on the formation of the melanin-like pigment which is characteristically produced by this microorganism.

INTRODUCTION

Bacterium salmonicida is the etiological agent of furunculosis in certain species of fish, particularly among the Salmonidae. The first description of this microorganism was given by Emmerich and Weibel in 1894 and since that time, many reports have appeared relating to the characteristics of this bacterium. However, a survey of the literature points to a surprising lack of agreement with respect to the physiological and biochemical characterization of *B. salmonicida*. A complete description of an unequivocal nature is therefore lacking and as a consequence only superficial reference to this microorganism can be found in Bergey's Manual of Determinative Bacteriology (1948). The situation is anomalous in view of the widespread occurrence and considerable economic importance of the disease caused by this bacterium. Accordingly, an investigation was undertaken to establish a set of descriptive data which could be used as a reference or a standard in the identification of this microorganism.

Much of the confusion concerning the description of *B. salmonicida* has had its origin in a failure to recognize the influence of oxygen, pH, and composition of the medium used in cultivation techniques. These factors are particularly applicable to the formation of the characteristic amber-black pigment which is primarily used as the criterion for presumptive bacteriological diagnosis of this type of infection in fish.

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It should be noted that the results of past experimental work are scattered in the literature, making it difficult for one to become familiar with the research which has been completed. Fortunately, this difficulty was overcome since an excellent and comprehensive review has appeared on furunculosis of fish (McCraw, 1952). The reader is therefore referred to this work for references concerning many of the original descriptions with which the present study agrees or disagrees

Methods

Ten cultures of *B. salmonicida* (S-1, 7, 9, 14, 17, 18, 20, 22, 23, 25) were utilized in these studies. All of the strains had been isolated from diseased fish obtained from widely scattered sections of the United States. The cultures were maintained at 6° C. on trypticase-yeast extract agar slants. Prior to each test, the microorganisms were transferred to fresh slants and incubated at 22° C. for 24 hours. A subculture was then made in nutrient broth (Difco) for the same time and temperature as indicated above. These subcultures then served as the inoculum for all of the tests to be described. Unless otherwise indicated, the incubation temperature was 20–22°C.

Description of the Bacterium

Morphology.—At the end of 18 hours of incubation on nutrient agar at 22° C., the microscopic picture may be somewhat confusing since some strains of the organism frequently exhibit a tendency to pleomorphism. The organism usually grows predominantly as short plump rods with rounded ends which approach a coccus form or the arrangement may take the form of diplobacilli (1 micron wide and 1.7–2 microns long) or chains of variable length; many coccoid forms (approximately 1 micron in diameter) singly and in pairs, are also evident. Filaments and definite cigar-shaped structures (8 microns long and 1 micron wide) and bipolar rods also may be found; it is not uncommon to find fused filaments as long as 40–50 microns. After 48 hours, there is a predominance of coccoid forms (approximately 1 micron diameter), singly and in pairs; diplobacilli are also present. In nutrient broth, the appearance of the microorganism is not as markedly coccoid as that described for cells grown on agar. In the former, there are many bacillary forms, singly and in pairs and an obvious tendency exists to form short and long chains of rods which are not usually fused into filaments. Some strains may show an abundance of bipolar rods. After 72 hours in broth or on agar extreme pleomorphism may be manifest in some strains. One may find cocci, rods, paired forms, many cigar-shaped structures, filamentous forms which stain lightly and contain heavily stained beaded areas, and irregular lobulated and enlongated rods. The coccoid forms at this time are usually much larger than those found at 48 hours. In other strains, even at the end of 6 days of incubation in nutrient agar and broth, the pleomorphic tendency is at a minimum and coccoid forms are predominant.

The organisms are gram negative; some tendency to bipolarity has been noted. They are non-motile, non-spore-forming and devoid of capsules (Anthony's method and India Ink technique) and non-acid-fast.

Cultural characteristics.—B. salmonicida is a facultative anaerobe growing best with unrestricted access to air. In nutrient broth, the optimum growth temperature was 20–22° C. The maximum growth temperature was 34.5° C., and the minimum temperature tested at which growth appeared was 6° C. The optimum reaction for growth in nutrient broth buffered at various values with buffer tablets was at pH 6.4; a secondary peak of growth stimulation appeared at 7.6 to 8.1. The intensity of growth was measured on a Beckman Model B Spectrophotometer (650 millimicrons). In buffered trypticase-yeast extract broth growth occurred between pH 5.3 and 9.0. Growth did not occur at a pH value of 5.3. Sterilization of the medium above pH 9.0 was considered impractical. Maximum growth occurred between pH 6.3 and 6.6 with a secondary growth peak at pH 8.6. In unbuffered trypticase-yeast extract broth the pH range for growth was between 5.4 and 9.0. Growth did not take place at pH 5.4. The pH values for optimal growth varied little and extended from 6.8 to 8.0. A similar plateau was noted in unbuffered nutrient broth. In nutrient broth after 24 hours of incubation, the growth of some strains was homogeneous in appearance with only a slight fine sediment in the base of the tube. In other strains, the growth had collected as a flocculent mass at the bottom of the tubes with a clear supernatant above. In these latter strains, one occasionally could note a light amount of growth adhering to the walls of the test tubes. In other strains in which homogeneous growth occurred, a small clear area could be detected in the top-most portion of the broth.

On nutrient agar plates, the colonies averaged less than 1 millimeter in diamter in 24 hours. They were punctiform, smooth, entire, convex, translucent to opaque, and without a pigment. At the end of 4 days, well isolated colonies averaged 1 to 2 millimeters in diameter. In 5 days a light straw-yellow color developed which could be reliably discerned only by comparison with an uninoculated control agar plate. In 6 days a light brown color appeared in the medium which was greatest in intensity in the area of heaviest growth. On nutrient agar slants in 24 hours, growth was abundant, filiform, glistening, opaque to transparent, butyrous, odorless, and colorless. A faint indication of pigment production could be noted in 3 days, however by the fifth day a definite light yellow-brown color developed in the medium. This coloration could be seen best by comparison against uninoculated slants.

Scant to negative growth resulted on eosin-methylene blue agar. On blood agar (veal-yeast extract agar plus 10 percent sterile defibrinated rabbit blood), beta hemolysis was exhibited in 48 hours. In 24 hours a brown pigment was noted in the area of heaviest inoculum. After 48 hours, the pigment began to change to an intense brown-black color.

Growth in plain and nutrient gelatin was best at the top with growth extending in a filiform to beaded manner to the base. Liquefaction was crateriform in 24 and 48 hours and changed to infundibuliform in 72 hours.

There was 75- to 90-percent liquefaction in 6 days and it usually was complete at the end of 8 days. A light brown ring of pigment appeared at the top of the gelatin in 9 days in all strains except S–7 and S–14. The latter strains failed to form pigment even after 38 days of incubation in this medium. In 13 days this ring became dark brown and extended downward a quarter-inch from the top; in 20 days the color had changed to a deep amber. On gelatin plates, the medium was pitted in 24 hours and liquefaction occurred along the line of streak. Liquefaction was complete in 90 hours in all but one strain (S–20, 5 days). A decided brownish pigment was produced by all strains in 8 days.

In nitrate broth, nitrates were reduced to nitrites in 24 hours; on nitrate agar the reduction was complete in 48 hours. Hydrogen sulfide was not produced. Hydrolysis of starch occurred in 48 hours and was complete in 3 to 5 days. Indole was not produced. The methyl-red test was negative, acetylmethylcarbinol was not produced, and growth did not occur in Koser's citrate broth; the urease test was also negative (7 days). Ammonia, determined by employing Conway units after the method of Fister (1950) and calculated as ammonia nitrogen, was detected after 8 hours in trypticase-yeast extract agar. There was slight acid formation (pH 6.5) in bromcresol-purple and Litmus milk in 24 hours and peptonization was 25-percent complete in all strains but S–1. Complete peptonization occurred in all strains in 7 days. The pH increased steadily and at the end of 14 days had reached a value equivalent to the uninoculated controls (pH 7.1), as checked in an electric pH-meter. A pigment was not visible at the end of this time. In trypticase-yeast extract, semi-solid agar, containing resazurin, growth extended to the bottom along the line of puncture and the dye was completely reduced in 48 hours. A positive test with paraphenylenediamine was obtained in 18 hours (Griffin, Snieszko, and Friddle, 1952a).

Various sugars, alcohols, and glucosides were sterilized by filtration through Selas porcelain filters (porosity No. 3) and incorporated into standard basal medium in 1-percent concentrations. The data in Table 1 are representative for the 10 strains employed. Unless otherwise indicated, the data represent observations made at the end of 24 hours of incubation at 20° C. All media were maintained for over 1 month before being discarded.

Growth Requirements

Although good growth was obtained in nutrient broth, far better growth was obtained upon the addition of yeast extract (Difco) in a final concentration of 0.5 percent. This was quantitatively measured in a Beckman Model B Spectrophotometer. A somewhat similar effect was noted after the addition of 1.0 percent tryptic digest of casein. However, the values of the readings in the latter case were between those obtained for nutrient broth with and without the addition of yeast extract.

An attempt was made to cultivate *B. salmonicida* in a mineral medium to which had been added an inorganic or organic carbon source such as:

Na_2CO_3, $NaC_2H_3O_2$, glucose, sucrose, lactose, and maltose in various combinations and permutations with sources of nitrogen such as NH_4Cl, NH_4NO_3, KNO_3, $(NH_4)_2HPO_4$, $(NH_4)_2CO_3$, and asparagine. The carbon sources were employed at a final concentration of 0.5 and 1.0 percent. The nitrogen sources were used at a final concentration of 0.1 percent with the following exceptions; NH_4Cl, 0.5 percent; asparagine, 0.3 percent. The

TABLE 1.—*Fermentation action of* B. salmonicida

[AG = acid and gas; "..." = negative after 39 days incubation at 20° C. All materials were sterilized by filtration and incorporated into the sterile basal medium at a final concentration of one percent]

Substance	Reaction	Substance	Reaction
Monosaccharides		Polysaccharides (cont.)	
Arabinose	AG[1]	Melezitose	...
Rhamnose	...	Starch	AG[2]
Xylose	...	Inulin	...
Dextrose	AG	Dextrin	AG[2]
Fructose	AG	Glycogen	AG
Galactose	AG	Glucosides	
Mannose	AG	Salicin	AG[3]
Disaccharides		Esculin	AG[2]
Lactose	...	Amygdalin	...
Sucrose	...	Methyl glucoside	...
Maltose	AG	Alcohols	
Trehalose	...	Glycerol	...
Melibiose	...	Erythritol	...
Cellobiose	...	Adonitol	...
Polysaccharides		Mannitol	AG
Raffinose	...	Sorbitol	...
		Dulcitol	...

[1] 4 days [2] 2 days [3] 3 days

mineral base to which the various substances were added was of the following composition in milligrams per liter of double-distilled water:

$MgSO_4$	200	K_2HPO_4	250
$FeSO_4.7H_2O$	20	KH_2PO_4	250
$ZnSO_4$	0.4	NaCl	5,000
$CuSO_4$	0.4	H_3BO_3	0.4
$CoCl_2$	0.4	$Na_2MoO_4.2H_2O$	0.4
$MnSO_4.H_2O$	1.0		

The pH was adjusted to 6.8 and the medium was distributed into screw-capped test tubes in 10-milliliter amounts and sterilized at 121° C. for 10 minutes.

Four strains of *B. salmonicida* (S–1, 9, 22, 23) were grown in nutrient broth for 48 hours; the cultures were then centrifuged and the supernatant broth decanted. The cells were resuspended in 0.9-percent saline, centrifuged, and again suspended in fresh saline. The above combinations of carbon and nitrogen compounds in mineral medium were then inoculated with 0.2-milliliter of saline suspensions of *B. salmonicida* and the tubes were incubated at 20° C. None of the combinations employed was found to support the growth of the microorganism after 12 days of incubation.

Another medium was then devised in which amino acids in the form of "vitamin-free," acid-hydrolyzed casein were added to the mineral base. The composition of this medium is given in Table 2. The inoculum was prepared and the tubes incubated in the manner described above. Good growth of *B. salmonicida* occurred in this medium in 24 hours and excellent growth was noted at the end of 48 hours.

TABLE 2.—*Composition of semi-synthetic medium for the cultivation of* B. salmonicida
[The pH was adjusted to 7.2 with NaOH. The medium was distributed in screw-capped test tubes in 10-milliliter quantities and autoclaved at 121° C, 10 minutes]

Constituent	Amount
Acid hydrolyzed casein ("vitamin free")[1]	50 milliliters
L-cystine	0.1 gram
Tryptophan	0.05 do.
Serine	0.10 do.
Glucose	5.0 do.
Mineral base	As formulated
Calcium pantothenate	1.0 milligram
Nicotinamide	0.05 do
Biotin	2.0 micrograms
Distilled water, to	1,000 milliliters

[1] 10-percent aqueous solution

The medium in Table 2 was further modified by substituting various amino acids for the acid-hydrolyzed casein. The composition of this medium is given in Table 3. This medium is of empirical definition and many of the components are probably not required. For example, the microorganism apparently does not require either tyrosine or phenylalanine since these

TABLE 3.—*Composition of basal medium for cultivation of* Bacterium salmonicida
[The pH was adjusted to 6.8; distilled water made up to 1 liter. Sterilized at 116° C for 10 minutes]

Constituent	Amount	Constituent	Amount
$MgSO_4$	200 milligrams	Adenine	10 milligrams
K_2HPO_4	25 do.	Guanine	10 do.
KH_2PO_4	25 do.	Uracil	10 do.
NaCl	5.0 grams	DL-alanine	500 do.
$CaCl_2$ anhydrous	50 milligrams	L-arginine.HCl	500 do.
Salts Solution[1]	1.0 milliliter	L-asparagine	500 do.
Thiamine.HCl	0.1 milligram	L-glutamic acid	1.0 gram
Nicotinic acid	1.0 do.	Glycine	500 milligrams
Nicotinamide	0.05 do.	DL-histidine.HCl	200 do.
Calcium pantothenate	1.0 do.	L-hydroxyproline	10 do.
Riboflavin	2.0 do.	DL-leucine	500 do.
Pyridoxine	2.0 do.	DL-lysine.HCl	60 do.
Pyridoxamine.2HCl	2.0 do.	DL-methionine	40 do.
Para-aminobenzoic acid	1.0 microgram	DL-proline	100 do.
Biotin	2.0 do.	DL-serine	100 do.
Choline.HCl	1.0 milligram	DL-threonine	50 do.
Inositol	1.0 do.	DL-tryptophan	50 do.
Folic acid	2.0 do.	DL-valine	50 do.
Putrescine	0.05 do.	DL-isoleucine	30 do.
B_{12}	15 micrograms	L-cystine	3.0 do.
Noble agar (Difco)	15 grams		

[1] Salts solution: $FeSO_4.7H_2O$, 5 grams; $ZnSO_4$, 0.1 gram; $CoCl_2$, 0.1 gram; $MnSO_4.H_2O$, 0.2 gram; $CuSO_4$, 0.1 gram; water to 250 milliliters

two amino acids can be withheld from the medium without any appreciable effect in the amount of growth at the end of a given period of time. Furthermore, most of the vitamins can likewise be eliminated. Additional work on the exact amino-acid requirements of *B. salmonicida* is obviously necessary.

Effect of Antibiotics

The *in vitro* sensitivity of *B. salmonicida* was determined through the use of Bacto "Sensitivity disks". Several strains (S–1, 9, 14, 20) of the microorganism were grown on trypticase-yeast extract agar for 48 hours, emulsified, and then suspended in nutrient broth. Sterile cotton swabs were used to spread the microorganisms over the surface of trypticase-yeast extract agar plates. Each test plate contained disks representing three concentrations of each of the following antibiotics: dihydrostreptomycin, penicillin, terramycin, aureomycin, bacitracin, and chloromycetin. The diameter of the zones of inhibition was measured at the end of 24 hours. The data indicated that *B. salmonicida* was sensitive even to the lowest concentrations (10 micrograms per disk) of the following: chloromycetin, aureomycin, and terramycin. The microorganism was unaffected by the low and intermediate concentrations of bacitracin, dihydrostreptomycin, and penicillin. Relatively small zones of inhibition resulted when disks of the latter three antibiotics containing the highest concentration were employed (20, 10, and 10 units respectively).

Pigment Formation

B. salmonicida produces a diffusible red-brown to dark-amber pigment when grown on trypticase-yeast extract agar. The experiments of Gutsell and Snieszko (1949) indicated that this was the best medium for the demonstration of pigmentation. The same authors (1948) also pointed to the ease of a presumptive diagnosis of furunculosis in fish, based on pigmentation, through the use of such a medium.

On trypticase-yeast extract agar slants, a light pink pigment first appears in the medium at the very tip of the slant at the end of 28 to 30 hours of incubation. In 48 hours the color of the pigment changes to a red-amber and extends downward for approximately 1½ inches from the tip of the slant. At the end of 72 hours of incubation half or more of the agar slant contains a brown-amber pigment. In 96 or more hours, practically the entire agar slant is filled with a coffee-brown pigment. The latter changes to an intense amber-black after prolonged incubation. It may be of interest to note that in the very early stages of the pigmentation process, the colonies themselves are essentially unpigmented. After additional incubation, the colonies also change to a brown color.

In trypticase-yeast extract broth, pigmentation is delayed sometimes as long as 10 to 12 days. This difference was found to be due, at least in part, to the fact that on agar medium, the pH quickly changes to alkaline regions as the microorganism grows; in broth, the reverse occurs with an initial

lowering of the pH value to acid regions. The latter then slowly begins to increase and at the time that a pigment forms in broth, the pH is alkaline. These observations are in accord with current concepts of melanogenesis, since an alkaline environment is an apparent prerequisite to the formation of these darkly colored products. However, it should be noted that the best pigmentation occurs at that pH at which the most luxuriant growth occurs. The present study has indicated that this value initially is approximately from 6.5 to 6.8. As a consequence of the metabolic activity of the microorganism, the pH then rapidly changes toward greater alkalinity. The importance of the direction of change of pH is further indicated by the observation that the addition of maltose delays the appearance of a pigment by as much as 24 to 48 hours. In the present study, this delay has been shown to result from the action of the microorganism on this carbohydrate to produce acids.

Oxygen is also prerequisite to pigment formation since anaerobic cultures will not pigment. Reduction in pigmentation can be obtained also by growing the microorganism in an atmosphere of approximately 10-percent CO_2 (candle jar method) or by merely tightening the caps of screw-capped culture tubes.

That the temperature of incubation is also important is indicated by the observation that progressive increases above 20 to 22° C. result in a corresponding decrease in the intensity of the pigment and at an incubation temperature at 32° C, pigmentation does not occur.

The composition of the medium is of paramount importance to pigment production. Griffin (1952) reported that a dark-amber to black pigment was produced in nutrient agar by the addition of either L-tyrosine or L-phenylalanine. That either of these two substances is the starting material for the production of a melanin-like pigment has been shown by Griffin, Snieszko, and Friddle (1952b), since a pigment is not formed in a defined medium which lacks either of these two amino acids.

Substrate concentration is also important. Progressive increases in the concentration of L-tyrosine ethyl ester up to 75-milligrams percent resulted in a corresponding increase in the intensity of the color of the pigment formed in a completely synthetic medium. Subsequent increases above this level did not result in any further visible changes in color. The addition of tyrosine ethyl ester to agar usually shortens the time necessary for the first appearance of the pigment; the time in broth is shortened by as much as 3 to 5 days. In broth, the addition of tyrosine ethel ester even in concentrations above 75-milligrams percent had no effect on the amount of growth produced as measured by a Beckman Model B spectrophotometer.

Substances other than L-phenylalanine or L-tyrosine will also act as substrates for the enzyme or enzyme systems in *B. salmonicida* concerned in the formation of a pigment. For example D-phenylalanine, glycyl-L-phenylalanine, and B-2-thienylalanine can substitute for L-phenylalanine. L-tyrosine ethyl ester, and glycyl-L-tyrosine can be substituted for L-tyrosine. The color and intensity of the resultant pigments vary according

to the particular material used. To cite but one example, a bright salmon-pink color is produced through the use of B-2-thienylalanine.

Conclusions

Despite the many contradictory descriptions of *B. salmonicida,* it may be stated that on the basis of the 10 strains employed in these studies, *B. salmonicida* appears to be remarkably consistent in its general cultural and biochemical characteristics. Much of the confusion arising from the earlier descriptions of this microorganism undoubtedly reflects the use of media which varied in composition from one laboratory to the next. Today, most research workers have at their disposal media of relatively standardized composition prepared commercially by several reliable firms. As a consequence, many of the differences in observations, due primarily to variations in methods of preparation of the media have been eliminated. This lack of standard media may account, at least in part, for the discrepancies noted between the present study and reports of former years concerning the action of *B. salmonicida* on maltose.

The different statements concerning the presence or absence of a pigment in gelatin, litmus milk, and various types of fluid and solid media are now readily understandable in the light of the present study. For example, differences in the amount of either or both of the two amino acids primarily concerned in pigment production (L-phenylalanine and L-tyrosine singly or in peptide linkage with other amino acids) could readily explain the variation in observations concerning pigment formation in gelatin and milk media. Not only are quantitative differences such as those described in this report of importance; also differences in pH, content of fermentable sugars, availability of oxygen, and incubation temperature are not without influence in the formation of a pigment by *B. salmonicida.* It may also be of interest to note that some investigators have stated that occasionally some strains of *B. salmonicida* were encountered which did not have the ability to form a pigment. The present studies also have indicated that slight strain differences do exist with respect to ability to produce pigment. For example, some strains apparently require slightly larger concentrations of tyrosine and/or phenylalanine to produce a pigment comparable to that produced by other strains in the presence of lower concentrations of either or both of these amino acids. One can therefore question the existence of all of such pigmentless strains which have been reported. Some, undoubtedly may actually be mutant strains of *B. salmonicida*—strains which have lost their abliity to produce the necessary enzyme or enzyme systems connected with the process of pigmentation. Others may represent microorganisms which require more than the average amount of the amino acids mentioned, before a visible pigment can be produced. However, until such time as these pigmentless strains have been isolated and studied, the question must remain unresolved.

The data presented in the present report may not only serve to establish

what may be considered as a 'model' description of *B. salmonicida,* but may also justify a change in the taxonomic position of this microorganism from the general class, *Bacterium,* to the new genus *Aeromonas* Kluyver and Van Niel.

Literature Cited

Breed, R. S., E. G. D. Murray, and A. P. Hitchens
1948. Bergey's manual of determinative bacteriology, 6th Ed. Williams and Wilkins Co., Baltimore, xvi + 1,529 pp.

Emmerich, R. und C. Weibel
1894. Ueber eine durch Bakterien erzeùgte Seùche unter den Forellen. Arch. für Hygiene., Bd. 21, S. 1–21.

Fister, H. J.
1950. Manual of standardized procedures for spectrophotometric chemistry. Standard Sci. Supply Corp., New York.

Griffin, P. J.
1952. Some factors influencing pigment production in *Bacterium salmonicida.* Bact. Proc., p. 53.

Griffin, P. J., S. F. Snieszko, and S. B. Friddle
1952a. A new adjuvant in the diagnosis of fish furunculosis caused by *Bacterium salmonicida.* Vet. Med., Vol. 48, pp. 280–282.
1952b. Some aspects of the biochemistry of melanin formation by *Bacterium salmonicida.* Jour. Bact. [Submitted for publication.]

Gutsell, J. S., and S. F. Snieszko
1948. Furunculosis in fish; its diagnosis and treatment. Vet. Med., Vol. 43, pp. 484–486.
1949. Dosage of sulfamerazine in the treatment of furunculosis in brook trout, *Salvelinus fontinalis.* Trans. Am. Fish. Soc., Vol. 76 (1946), pp. 82–96.

McCraw, B. M.
1952. Furunculosis of fish. U. S. Dept. Interior, Fish and Wildlife Serv., Special Sci. Rep.: Fish. No. 84, 87 pp.

MIGRATIONS OF SALMONIDS IN SAND CREEK, OREGON [1]

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ABSTRACT

A picket barrier with upstream and downstream fish traps was maintained on Sand Creek, a small Oregon Coast stream, during 4 upstream and 3 downstream fish runs (1946–1949), and a smaller trap was operated on a tributary during part of 1947. Two species of trout, coast cutthroat, *Salmo clarki clarki* Richardson, and steelhead, *Salmo gairdneri gairdneri* Richardson, and two species of Pacific salmon, the coho salmon, *Oncorhynchus kisutch* (Walbaum), and the chum salmon, *Oncorhynchus keta* (Walbaum), made spawning runs during the fall and winter. Downstream migrations of fry and fingerlings, and of spent adult trout, occurred in the spring.

Physical data on Sand Creek included water temperatures and information on occurrence and magnitude of freshets. Records on fish trapped included the numbers of salmonids in each migration, lengths, weights, sex ratios in upstream runs, loss in weight after spawning, and survival rates.

The results of this experiment indicate the need for a careful study of environmental and ecological conditions in order that a trapping structure may be adapted to extremes of water levels and to the habits of all species of migratory fishes found in the stream.

INTRODUCTION

The Sand Creek project had as its primary aim the accumulation of data on the life history of the cutthroat trout. Although Sand Creek is a minor coastal stream and not of any importance for angling, it was considered suitable for the experiment for several reasons: its size permitted the construction of traps and accessory structures within budget possibilities; it is typical of coastal streams in its general character; and it was known to have an appreciable cutthroat trout population.

The project was originally planned for a 5-year period, from the fall of 1946 to that of 1951. Its termination at the end of 1949 was brought about by the traps' unsuitability to prevailing conditions and by a change in the general program.

DESCRIPTION OF SAND CREEK

Sand Creek is located on the northern coast of Oregon in Tillamook County. It is about 5 miles long and includes three forks which arise on a 2,000-foot peak forming the backbone of Cape Lookout. Their gradient

[1] Published by permission of the Chief, Division of Fisheries.

is steep until they unite some 3 miles above the trap site. The main stream flows with moderate current through partly logged land for 1 mile and through willow- and alder-lined pastures for much of its lower course. The average width of the main stream is 12–15 feet in summer. The minimum flow measured in Sand Creek was 2.2 cubic feet per second (September 9, 1946) and the maximum estimated flow was between 300 and 400 cubic feet per second (February 9, 1949). The stream is characterized by a good balance between pool and riffle, with much shelter for fish. The principal tributary, Jewell Creek, enters just below the head of tidewater, and another main tributary joins the stream about a quarter-mile above the trap site.

Sand Creek flows into Sand Lake, a shallow tidal basin some 2 miles long and 1 mile wide. At low tide only mud- and sand-bottom channels and a pool of perhaps an acre are present. High tides cover a large area of mud and sand flats; flood tides back up over marsh-grass pastures. Characteristic forms in Sand Lake are flounders, surf perch (spawning), crabs, and clams. The mouth of the "lake" is a channel of varying length, width, and depth which crosses the sand beach.

Trap Construction

The trap site, a half-mile above tidewater, was widened from 20 to 40 feet. The stream bed was dug out, and three hemlock logs were laid across the pit and anchored into the bank. A flooring of 2- by 12-inch plank was laid across the logs, tripods of 4- by 4-inch timber were erected on it, and a 45° sloping fence of pickets spaced 1 inch apart was attached to the upstream side. A 6-foot catwalk of 1-inch-spaced pickets provided footing for cleaning the fence. Later experience suggested that a solid weir such as that described by Taft (1936) might have functioned more consistently under the conditions of widely fluctuating water levels.

The upstream and downstream traps were together at one end of the rack. A lateral opening led into the downstream trap. Water poured from the downstream trap through a grill of 1-inch-spaced pickets into the upstream trap, whose V-entrance was two 12-inch steps above low-water levels. A second downstream trap was subsequently built into the rack 3 feet from the first trap. It had two successive chambers, the lower with a small opening for fingerlings.

During the spring downstream-migration period the face of the picket fence and the opening between the traps were covered with ½-inch-mesh wire cloth.

Water Temperatures

Mean, maximum, and minimum water temperatures for each month during 3 years (1947–1949) are recorded in Table 1. The highest temperature, 65°F., was recorded on September 9, 1948; the lowest, 33°F., occurred on January 23, 1949.

TABLE 1.—*Water temperatures in Sand Creek (F.°), 1947-1949*

Month	1947			1948			1949		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	41.6	47.5	36.0	44.9	49.5	38.0	38.5	45.0	33.0
February	45.7	50.0	39.0	43.4	48.5	36.0	43.1	49.5	37.0
March	47.0	53.0	41.5	46.5	52.5	42.5	46.6	51.0	41.5
April	51.2	58.5	45.0	48.7	54.5	43.0	49.6	55.5	44.0
May	53.9	61.0	47.5	51.1	57.5	46.0	52.3	57.5	45.0
June	54.4	60.0	50.0	55.8	64.0	50.5	54.7	60 5	49.5
July	56.8	62.0	50.0	58.0	62.5	52.0	57.7	64.0	52.5
August	58.3	63.0	53.5	58.2	63.5	53.5	58.3	63.5	53.5
September	56.5	63.5	49.5	56.1	65.0	48.0	56.8	63.0	52.0
October	53.2	59.0	49.0	50.6	56.0	43.5	48.7	55.0	41.0
November	48.7	52.0	43.5	46.4	50.0	42.5	49.2	52.0	46.0
December	47.6	50.5	43.5	45.4	49.0	40.0	45.6	49.0	40.0

Fluctuations of Stream-Level

The heavy rainfall of the region (averaging 96 inches at Tillamook, 18 miles to the north) caused rapid fluctuations in stream flow, the highest levels occurring during southwest storms. If rises in water level of 10 inches and over are considered as freshets, an average of 10 occurred per rainy season, with an average rise of 29 inches (range 11–60 inches). The rainy season extends from October to April, but freshets raising the stream over 30 inches have occurred also in May and June.

During the winter of 1946–47, the willow-choked stream course below the rack caused the stream to back up over the catwalk. It is calculated (by ratio of marked to unmarked fish returning downstream) that at least 48 percent of the upstream-migrating salmonids swam over the rack. Cleaning out excess willow growth in the following summer solved the problem of backing up of the stream.

Freshets came through and over the top of the rack and catwalk during succeeding runs. During the 1948 downstream run, water poured through the catwalk for 2 days. Several spent cutthroat and steelhead trout went over the rack in the downstream direction. In November 1948, a high freshet came over the rack for several hours and unknown numbers of salmon and trout passed upstream. On 2 days in February 1949, water poured over the rack for several hours. Some spent cutthroat trout probably passed downstream. During the remaining runs all sea-run fish at the rack are believed to have been counted, except those which dropped back downstream from below the rack.

Upstream Migrations

Upstream-migrating fish (except those that escaped over the rack during high water) were marked by removal of the adipose fin. Thus total numbers of fish in runs could be calculated from the ratio of marked to unmarked fish returning downstream.

Table 2 lists the calculated or actual numbers of salmonids in spawning runs during 3 full seasons and most of the fourth. Only sea-run fish, as far as could be determined, are included. Since some fish escaped over the rack in the upstream direction during freshets, calculated upstream-trap

Table 2.—*Upstream migrants counted at the Sand Creek rack*

Species of fish	Year			
	[1]1946-47	1947-48	1948-49	[2]1949
Cutthroat trout	224	92	81	94
Steelhead trout	147	70	47	..
Coho salmon	233	449	184	57
Chum salmon	495	363	189	20

[1] Oct. 21, 1946–Sept. 30, 1947
[2] Oct. 1–Dec. 31, 1949

counts for some years are undoubtedly low (that is, part of the correction for escape past the rack during upstream movement was lost by reason of similar escape during the later downstream movement). Because of the short duration of the freshets and because of the periods in which they occurred, it is believed that the error is not greater than 10 percent.

Cutthroat trout of less than sea-run size (on the average 11 percent as many as the larger fish) occurred in the upstream trap during spawning runs, but many more could have passed between the pickets in the trap and rack. Several cutthroat fingerlings wandered into the upstream trap each spring and summer. A sea-run cutthroat fresh from the ocean was caught in the upstream trap in July 1947. Such fish, called "bluebacks" by local anglers, generally stay in tidewater and the lower stream until the fall freshets. Relatively few steelhead fingerlings were trapped enroute upstream.

The entrance of the upstream trap was more easily found by the two species of trout than by the salmon, but all of the salmonids tended to swim under the catwalk and struggle against the pickets. The chum salmon showed little capacity for finding the trap's steps and also hesitated to jump them and enter the trap. Hence it was customary to capture fish under the catwalk by means of a long-handled dip-net. Most of these captures were made within an hour after sunset, when migratory activity seemed greatest.

The clearing of the stream for a distance of some 200 yards below the rack caused an increase in current velocity which in turn was responsible for washing out much bottom mud and debris and exposing clean gravel. During high water it was impossible to net under the rack. The fish struggled against the pickets, failed to enter the trap, and finally dropped back onto the cleaned gravel where they spawned. This retreat of the fish below the rack accounts in large part for the reduced counts of salmon and steelhead trout in the last 2 years. However, coincident reductions in coho and chum salmon catches were widely reported along the coast. Most of the chum salmon entering Sand Creek spawn in the lower tributary, Jewell Creek, whose gravel riffles extend to its mouth. There also, the runs were much smaller during the later seasons.

In Sand Creek the extreme limits of the runs of chum salmon were October 28 and December 12 with a peak in the middle of November. Chum salmon were broadly tolerant in their selection of spawning sites, making redds in deep or shallow water of slow or rapid flow. Where they were crowded below the rack, later spawners often dug up redds previously made, and fingerling trout were observed to eat the eggs.

Coho salmon were seen from the first freshets in October until as late as February 21 in one year when January was very cold. Seasonal peaks have occurred in either November or December. Coho salmon were caught in tidewater nets set for chum salmon; but, since the netting of coho salmon was illegal, though unavoidable, their numbers cannot be known. They were also taken by sport anglers.

Male coho salmon tended to predominate, especially during the early and late parts of the runs. A large proportion of the males were jacks—small mature fish generally between 15 and 20 inches long.

The steelhead trout, as is commonly found in small streams, tended to run late in the season when they were ripe or nearly so. A few steelheads were seen as early as December, but the greatest numbers arrived in March and fewer in April. Like the salmon but to a lesser extent, the steelheads tended to fall back from the rack and spawn below it. Nest-making disrupted some salmon nests, but others had been vacated already by emerging fry.

Cutthroat trout came upstream on the first October freshets and continued sporadically through December with stragglers arriving as late as February. The earliest migrants were quite green, which circumstance added to the difficulty of sex determination of the smaller fish.

Lengths and Weights of Upstream Migrants

Average fork lengths and ranges in length of upstream migrating salmonids handled at the Sand Creek Rack in each year, are given in Table 3, and weight data for the two species of trout in Table 4.

The sea-run steelhead and cutthroat trout were accompanied on their upstream runs by smaller trout from the lower stream and tidewater. The few steelhead fingerlings were probably not mature, but undoubtedly many of the non-sea-run cutthroat trout were mature. Cutthroat males have been found mature at 4 to 6 inches in length and females at 6 to 8 inches in length.

An arbitrary division between smaller non-sea-run cutthroat trout and larger sea-run trout was set at 11 inches. Length-frequency distributions and scale examinations support this choice, although a few trout in the 10-inch group appeared to have spent some time at sea.

Sizes of steelhead trout are similar to those in larger streams in the area (Sumner, 1948), but lengths of salmon reflect some earlier selective elimination of the larger fish by gill-nets.

Sex Ratios

The sex ratios of sea-run cutthroat trout showed a tendency toward predominance of females (1.0 males to 1.6 females in three seasons). Some difficulty was experienced in the determination of sex, since most of the fish were green. Cramer [2] found a 1.1:1.0 sex ratio among cutthroat trout trapped at the Alsea Trout Hatchery, on the Alsea River about 65 miles south of Sand Creek.

The sex ratio of steelhead trout was 1:1 in two seasons and 1.2 males to 1.0 females in the third season. Steelhead jacks accompanied the runs of large steelhead trout, but they did not contribute to a surplus of males

[2] Cramer, Fred K. (1939). Cutthroat studies. Unpublished report, Dept. of Fish and Game Management, Oregon State College, Corvallis.

TABLE 3.—*Fork lengths (inches) of salmonids migrating upstream, Sand Creek, 1946-1949*

Species and size groups	Year							
	1946-1947		1947-1948		1948-1949		1949	
	Average	Range	Average	Range	Average	Range	Average	Range
Cutthroat trout								
11 inches and over	13.7	11.7–17.5	13.8	11.0–18.6	13.5	11.1–16.8	13.5	11.5–16.8
under 11 inches	5.4	4.0–10.1	6.9	4.6–10.7	5.6	4.2–10.6	7.5	4.9–10.3
Steelhead trout								
Sea-run	23.1	15.0–30.3	23.7	16.6–31.7	25.5	15.2–31.7	....	.....
Non-sea-run	....	4.0	5.8	5.2, 6.5	....	.....	....	.....
Coho salmon	19.0	13.9–32.2	22.5	12.7–37.0	21.8	12.9–32.4	22.7	15.3–31.5
Chum salmon	26.3	21.5–30.6	25.0	19.5–32.0	27.3	22.5–32.4	24.9	23.3–26.4

TABLE 4.—*Weights (pounds) of cutthroat and steelhead trout migrating upstream, Sand Creek, 1946-1949*

Species	Year					
	1947-1948		1948-1949		1949	
	Average	Range	Average	Range	Average	Range
Cutthroat trout.....	[1]1.06	0.56– 2.94	0.90	0.50– 1.56	0.91	0.53–1.84
Steelhead trout.....	[2]5.4	1.81–10.31	6.6	1.38–11.31	....	.....

[1] Average fork length of 60 fish weighed, 14.1 inches (11.7–18.6 inches)
[2] Average fork length of 48 fish weighed, 23.9 inches (17.3–29.6 inches)

as did the jacks of the coho salmon. The runs of the latter were strongly biased toward males, with sex ratios varying in three seasons from 2.2 males to 1.0 female to 3.7:1.0. Selection by gill-nets probably contributed to the abundance of jacks, since fish of this size escaped more easily than did larger individuals. Also the jacks could enter the trap more easily than the larger fish, which had to force their way between spruce fingers forming a V-entrance. The sex ratios of chum salmon showed equal numbers of males and females in two years but a predominance of males in the other two years—1.7:1.0.

Downstream Migrations

The main period of observed downstream migration of salmonids in Sand Creek was from mid-March to mid-June, with a peak about May 1. Dead and dying salmon drifted downstream from early November to March. Occasional spent cutthroat trout came downstream from December throughout the winter, but the main body of both sea-run cutthroats and adult steelhead trout formed strong peaks during the principal migration period. Hatchery-reared cutthroat trout, liberated during late winter and spring, migrated coincidentally with the wild fish, though only small numbers of the hatchery trout migrated.

The numbers of fingerlings taken at the rack during their downstream migrations are shown in Table 5. Both live and dead fish are included. Turbulence in the original downstream trap, mostly during freshets, caused many deaths, especially among coho salmon fingerlings. Some fish were killed by being caught against the screen which covered the picket fence during the downstream runs. Mortalities in 1947, 1948, and 1949 were as follows: cutthroat trout—41, 74, 39; steelhead trout—6, 3, 37; coho salmon—110, 288, 176.

Chum salmon are not included in the tabulation of downstream migrants, since the fry drop downstream as soon as they emerge from the gravel, and the traps could not stop such small fish (see the later section on the downstream fry trap on Jewell Creek).

Unknown numbers of fingerlings passed downstream over the rack during freshets. The main part of the downstream run was unaffected in

1947 and 1949, but high water could have caused considerable uncounted escapement in 1948.

The average fork lengths of downstream fingerling migrants are shown in Table 6. Hatchery-reared cutthroat trout are included in the counts of Table 5, since they contribute to upstream spawning migrations; but they are not included in the length averages, which they would cause to be higher than the true average for wild trout.

TABLE 5.—*Fingerling counts in the downstream trap at Sand Creek, 1946-1949*

Species	Year		
	[1]1946-47	1947-48	1948-49
Cutthroat trout[2]	834	1,580	530
Steelhead trout	313	329	315
Coho salmon	1,165	1,355	1,100

[1] Oct. 21, 1946–Sept. 30, 1947; other years, Oct. 1–Sept. 30
[2] Under 11 inches in length

TABLE 6.—*Fork lengths (inches) of salmonids migrating downstream, Sand Creek, 1946-1949*

Species	Year					
	1946-47		1947-48		1948-49	
	Average	Range	Average	Range	Average	Range
Cutthroat trout[1]	6.4	3.2–10.6	5.6	2.7–10.9	5.6	3.4–10.7
Steelhead trout	6.3	3.2– 9.2	5.6	1.2– 8.0	5.9	1.5– 7.5
Coho salmon	4.2	1.3– 7.2	4.3	1.0– 6.0	4.1	1.5– 5.6

[1] Wild fish only

SURVIVAL OF SALMONIDS

Of three upstream runs of cutthroat trout from the sea, an average of 32 percent returned downstream alive. They had lost about one-third of their upstream weight (average of two runs). The survival after spawning of three runs of steelhead trout averaged 52 percent. Their average loss in weight was also about one-third. Since there was some uncounted escapement downstream during freshets, the above are minimal estimates of survival rates, except perhaps in the 1948–49 migration year, when uncounted escapement of cutthroat trout occurred during both upstream and downstream migrations.

All fingerlings of the 1946–47 downstream run were marked, and cutthroat trout only in succeeding runs. The later returns of 1946–47 fingerlings from the ocean as mature fish, expressed as percentages of the numbers of downstream migrants were: cutthroat trout, 1.56 percent; steelhead trout, 2.7 percent; coho salmon, 0.85 percent. The actual survival of steelhead trout and coho salmon was probably higher than the

percentages indicate, since some upstream-migrating fish spawned below the rack and hence were not included among the returns. Cutthroat trout fingerlings of the 1948 downstream run showed a higher return in two succeeding upstream runs—2.15 percent.

Other Species Caught in the Sand Creek Trap

In addition to the four salmonids heretofore treated, one chinook salmon jack, *Oncorhynchus tschawytscha* (Walbaum) occurred during the 1949 upstream run. This species had been reported caught by anglers from Sand Lake.

Other vertebrates and lower forms taken, mostly in the downstream traps, included: Pacific three-toothed lamprey, *Entosphenus tridentatus* (Gairdner); brook lamprey, *Lampetra planeri* Bloch; prickly sculpin, *Cottus asper* Richardson; newt, *Triturus* sp.; Pacific giant salamander, *Dicamptodon ensatus* (Eschscholtz); Northwestern toad, *Bufo boreas boreas* (Baird and Girard); Oregon red-legged frog, *Rana aurora aurora* (Baird and Girard); bullfrog, *Rana catesbeiana* Shaw; and crayfish, *Astacus* sp.

The Downstream Fry Trap on Jewell Creek

A fry trap was constructed in Jewell Creek, the principal tributary of Sand Creek near its confluence with the main stream below the rack. The trap, which was made of 1/6-inch mesh wire cloth, was operated from February 23, 1947, through most of the downstream migration period. A lead-in fence of the same gauge wire cloth extended diagonally upstream from the trap about halfway across the stream. A ½-inch-mesh screen extended halfway across the remainder of the stream. The fence thus covered three-fourths of the stream width.

The run of chum salmon fry had begun before the trap was installed, reached a maximum during the second week of April and fell off rapidly thereafter; the last fry were seen on April 29. The total number trapped was 16,200 (large numbers of mixed chum and coho salmon fry were "counted" by weighing).

Although coho salmon which mature in the ocean usually show one stream annulus on their scales, their fry moved downstream in considerable numbers. The movement had begun before the trapping started, an early peak coinciding with the trap's installation. It was a low peak, probably resulting from October or November spawning. The principal peak in the run of silver salmon fry occurred between March 16 and 22, 3 weeks earlier than the maximum for chum salmon. The main run was practically over by the end of April. The total number of coho salmon fry trapped was 3,320.

Although scales from adult steelhead trout almost invariably show

from 1 to 3 years of stream growth, enough steelhead fry were trapped to indicate a definite migration, at that stage. They were first seen on May 7, greatest numbers occurred in the second week of June, and the run was over by mid-June. The total number trapped was 315.

The chum salmon fry averaged 1.54 inches in fork length on both March 24 and April 21; the lack of change in length suggests that they were moving out of the stream as they emerged from the redds. This suggestion may also apply to the coho salmon, whose average lengths were; February 24, 1.62 inches; March 16, 1.51 inches; and April 14, 1.53 inches. Steelhead trout fry also maintained a fairly uniform size throughout their run.

The downstream trap also took a few steelhead, cutthroat, and coho salmon fingerlings. Other animals trapped included: sculpins, *C. asper;* lampreys, *Entosphenus* and *Lampetra;* salamanders, *Dicamptodon;* and crayfish, *Astacus.*

The Problem of Adjusting Weir Construction to Local Conditions

Although the Sand Creek fish-trapping project contributed to knowledge of fishes in the stream, it failed in certain respects. The primary shortcoming was the failure of the rack to trap all the fish at low and high water levels. Fish passed upstream and downstream uncounted, and many fish failed to find the upstream trap entrance.

In addition, the normal stream pattern was disrupted by the rack, even though not enough to lead to incorrect conclusions as to general migration periods. Moreover, the upstream trap entrance favored smaller fish, which may thus have caused slight reductions in the estimates of average sizes of salmon and steelhead trout. Another disadvantage was the killing of downstream-migrating fingerlings by water pressure against screens.

For situations in which wide fluctuations in water level occur, the solid weir with suspended metal plates overhanging the weir's crest, as used in Waddell Creek, California (Taft, 1936), seems better suited than a rack.

The Wolf trap (Wolf, 1951) appears to be excellently adapted to small streams for trapping downstream migrants only. It would seem, though, that the screens could easily be damaged by logs which frequently caused difficulties during freshets in Sand Creek. A system of booms and piling above the trap could largely eliminate this hazard.

The Michigan weirs described by Carbine and Shetter (1945) appear to be well adapted to the situations described, though it is doubtful whether any of them would be better suited to withstand freshets than the Sand Creek rack.

The principle of utilizing an area of maximum width and minimum rate of flow practiced in Lakelse River, British Columbia (Brett, 1948) overcame the problems imposed by the narrow more rapid stream sections. The same plan could perhaps have been adapted to the tidewater section of Sand Creek.

Literature Cited

Brett, J. R.
1948. The design and operation of a trap for the capture of migrating young sockeye salmon. Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 97–104.

Carbine, W. F., and David S. Shetter
1945. Examples of the use of two-way fish weirs in Michigan. Trans. Am. Fish. Soc., Vol. 73 (1943), pp. 70–89.

Sumner, F. H.
1948. Age and growth of steelhead trout, *Salmo gairdnerii* Richardson, caught by sport and commercial fishermen in Tillamook County, Oregon. Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 77–83.

Taft, A. C.
1936. The Waddell Creek experimental station for trout and salmon studies. Cal. Fish and Game, Vol. 22, pp. 99–104.

Wolf, Philip
1951. A trap for the capture of fish and other organisms moving downstream. Trans. Am. Fish. Soc., Vol. 80 (1950), pp. 41–45.

CORRELATION OF RAINFALL WITH THE TEXAS CATCH OF WHITE SHRIMP, *PENAEUS SETIFERUS* (LINNAEUS)

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Abstract

The young of the white shrimp, *Penaeus setiferus* (Linnaeus), grow up in estuarine waters the salinity of which is governed by rainfall. The Texas shrimp fishery was well started by 1927. From that time until 1936, catches were relatively low. The fishery underwent a period of growth and high-level catches have been obtained from 1937 to the present. During that period the annual catch in pounds of any one year shows a correlation coefficient of 0.883 with the State's average rainfall of the same year and 2 previous years. Essentially, there were 2 blocks of dry years with a period of wet years between, during which the catches were low and high, respectively. Decline of the white shrimp catch has been sharp with the recent drouth, but it is expected to rise when the drouth breaks. Whether the correlation is directly with salinity *per se* or some unknown factor governed by salinity is not known.

Introduction

For a number of years people concerned with shrimp have been interested in influences of minor climatic variations, such as drouths and hard cold waves, upon the total catch. It may be stated briefly that hard cold waves, which have an extreme effect on Texas fish populations (Gunter, 1952), have less effect on shrimp and the recorded occurrences of cold-waves and corresponding catch statistics are too few for fruitful analysis of that question at present.

The young of the white shrimp, *Penaeus setiferus* (Linnaeus), grow up in estuarine waters. The intimate connection between the estuarine environment and this shrimp is shown by the great superiority of Louisiana as a producing area. In the days when the white shrimp was dominant, Louisiana produced more than all other states combined. Viosca (1927 and 1938) pointed out the temporary benefits to Louisiana marine fisheries resulting from floods and crevasses. These benefits included local increases in the shrimp population, which were presumed to be due to influx of nutrient salts into the estuarine waters. Whether this commonly recognized connection between estuarine conditions and the production of white shrimp is due to salinity *per se,* nutrient salts washed in from land, or some more complicated ecological relationship, the relationship is detected or indicated by salinity. The salinity of the bay systems is obvi-

ously governed by the runoff of drainage areas of the various bays (*cf.* Collier and Hedgpeth, 1950). However, runoff figures are not complete and have not been summarized at least in Texas. On the other hand, rainfall may also be said to govern the salinity of the estuarine areas and figures on total rainfall are readily available. All Texas rivers, except the Red River, drain to the Texas coast and thus the State is a geographical unit with regard to runoff of rainfall into the sea.

Recent Developments in the Shrimp Fishery

In Louisiana in 1945 and in Texas in 1947 the white shrimp began to decline and the fishery turned to the brown shrimp, *Penaeus aztecus* Ives, and the pink shrimp, *Penaeus duorarum* Burkenroad. Louisiana fishermen came to Texas and explored the offshore waters out to 60 fathoms. Fishing of out-of-state waters began and the catch was brought to Texas ports. Brown and pink shrimp from the continental shelf off Mexico are now lumped with Texas white and brown shrimp and listed as the Texas catch. Thus, only statistics before 1947, when the total catch was white shrimp, can be used for correlations with weather records without corrective factors. However, the white shrimp catch reported for Texas comes from Texas waters except for a negligible percentage, and estimates of this catch have been made by the Fishery Market News Service. Today, Texas ranks close to Louisiana in shrimp landings (60,000,000 pounds per year) but the total catch from Texas waters is unknown and, since three species are involved, the bare records are valueless except as total landings. It behooves the officials of the federal and state governments concerned with statistics to remedy the situation if shrimp statistics are to be worthwhile.

Changes in the shrimp fishery have been mentioned in several places but have not been fully described anywhere. They have taken place so rapidly that state officials concerned with statistics have not kept up with them. One of them assured us in March 1951, that practically no pink shrimp from Campeche were landed in Texas and that most of them went to Key West. The reverse was true. Texas boats developed the Campeche pink shrimp fishery, but the fishermen practically lost interest in it with the sharp rise in brown shrimp catch closer to home waters in the latter part of 1951. Because of this situation, we collected our own statistics on a minor scale.

Texas White Shrimp Catch and Total Rainfall

The Texas shrimp industry was fairly well started by 1927. The depression prevented rapid growth and for a period of about 10 years there was a relatively stable, slowly increasing fishery. Table 1 shows the shrimp catch and the average rainfall for the State in those years. The rainfall fluctuated about a mean of 30.19 inches and the shrimp catch averaged 11,074,000 pounds. No particular correlation between catch and rainfall is to be seen.

TABLE 1.—*Total shrimp catch and the annual rainfall the State of Texas, 1927-1936*
[Catch per trawl was furnished by the Texas Game and Fish Commission. Catch records are from the Fish and Wildlife Service reports]

Year	Total production of shrimp (thousands of pounds)	Average rainfall (inches)	Catch per trawl (thousands of pounds)
1927	11,832	27.77	..
1928	7,774	29.03	..
1929	9,415	31.17	..
1930	10,189	29.67	..
1931	13,814	29.26	..
1932	9,244	34.06	..
1933	.....	25.96	..
1934	16,359	26.78	92
1935	.....	37.48	..
1936	9,963	30.71	37

The period from 1936 to 1947 was considerably different. The number of shrimp-trawl licenses increased from 251 in 1936–37 to 1,000 in 1948–48. This was a period of increased growth of the fishery. The catch per trawl declined from an average of 46,000 pounds per year during 1937–1943 to 23,000 pounds in the 1944–1947 period. There is some indication that the maximum annual production was reached at about 22,000,000 pounds in 1942. Nevertheless, the white shrimp production did not fall until 1948, 6 years later, and 5 years after the annual catch per trawl had fallen an average of 50 percent. This information is shown in Table 2.

The life cycle of shrimp is relatively short and if the sharp decline in white shrimp were caused by fishing pressure, it should have come earlier than it did. Instead, the population indicated a remarkable resiliency against fishing pressure. If the total catch was not close to the possible

TABLE 2.—*Total shrimp catch and annual rainfall for Texas, 1937-1951*
[Catch records are from the Fish and Wildlife Service, where available, and the Texas Game and Fish Commission, with a correction of one-fifth added to the latter. The 1947, 1950, and 1951 estimates for white shrimp is by the New Orleans Office of Fishery Market News Service. The 1948 and 1949 estimates are our own]

Year	Total production (thousands of pounds)	Production of white shrimp (thousands of pounds)	Average rainfall (inches)	Catch per trawl (thousands of pounds)
1937	16,905	Same	26.78	61
1938	16,365	do.	27.18	56
1939	11,173	do.	24.69	35
1940	14,779	do.	35.04	39
1941	19,319	do.	43.53	43
1942	21,785	do.	33.23	45
1943	22,916	do.	25.39	45
1944	18,615	do.	36.18	25
1945	15,722	do.	33.42	19
1946	21,521	do.	37.97	24
1947	24,211	21,791	26.83	25
1948	22,416	14,900	24.16	21
1949	33,668	12,010	34.34	26
1950	42,503	12,651	25.17	26
1951	60,648	7,278	21.09	26

maximum in the early years, it would not necessarily show correlation with rainfall or any particular factor. Records of catch per trawl or per unit are lacking for most of these years. In contrast, if the catch approached the annual possible maximum in the later period, as indicated by the maintained high catch in the face of a falling catch per unit gear, the catch would fluctuate with environmental factors.[1]

Comparisons of the catches from 1937 to 1951 with total rainfall show that in 9 cases out of 15, higher or lower than average production came in years in which the rainfall exhibited similar departure from the mean year. The coefficient of correlation is only 0.419; but if the catch is related to the previous year's rainfall, the correspondence is 11 out of 15 and the coefficient of correlation is 0.631. This increased value indicates a lag effect of rainfall. For the present, comments on the possible reasons for this lag will be deferred. Thus, annual catches, and the average of same and the previous year's rainfall show a correlation of 0.674. Averages of 2-year catches and average rainfall of the first year and the previous year (for example 1941 and 1942 catch with 1941 and 1940 rainfall) show a coefficient of correlation of 0.750; annual catches and average rainfall of the 2 previous years give a correlation of 0.739. Finally, annual catches show a correlation of 0.883 with average rainfall of the same year and the 2 previous years. Examination of Table 3 shows that there were 3 blocks

TABLE 3.—*Average Texas production of white shrimp and rainfall for three sets of years*

Comparison of rainfall and production for corresponding years

Year	Average annual rainfall (inches)	Average annual production (thousands of pounds)
1937-1939.....	26.22	14,614
1940-1946.....	34.96	19,237
1947-1951.....	26.31	13,726

Comparison of rainfall of one set of years and production of a set of years one year later

Years of rainfall	Average annual rainfall (inches)	Years of shrimp production	Average annual production (thousands of pounds)
1936-1939.....	27.34	1937-1940	14,802
1940-1946.....	34.68	1941-1947	20,738
1947-1951.....	27.87	1948-1951	11,710

of years from 1937 to 1951 of lower and higher rainfall, which would give a cumulative higher or lower salinity for the bays. High production corresponded with the period of relatively wet years from 1940 to 1946, while low production corresponded with the 2 series of dry years before and after the wet period.

[1] It should be noted that the shrimp fishery is one in which the maximum possible catch of the commercial fishery for any year may coincide with the maximum equilibrium yield (see Burkenroad, 1951, and literature cited by him for definition). However, this matter will have to be discussed in another place.

In 1947 the white shrimp production was almost 22,000,000 pounds. That was the last peak year. The decline since has been sharp and serious and it was the chief factor causing fishermen to turn to the brown and pink shrimp. The New Orleans office of Fishery Market News Service estimated that in 1951 the Texas white shrimp production was slightly over 7,200,000 pounds. The drouth continues and probably the white shrimp catch of Texas will remain low for a few more years, but there seems to be good reason to expect that production will approach its former level, with about a 2-year lag, as the drouth breaks.

Literature Cited

Burkenroad, M. D.
1951. Some principles of marine fishery biology. Pub. Inst. Marine Sci., Vol. 2, No. 1, pp. 177–212.

Collier, A. W., and J. W. Hedgpeth
1950. An introduction to the hydrography of the tidal waters of Texas. Pub. Inst. Marine Sci., Vol. 1, No. 2, pp. 125–194.

Ezekiel, W. N.
1942. Cotton root rot, the weather and cotton yields. Proc. and Trans. Texas Acad. Sci., 1941, Vol. 24, pp. 63–68.

Gunter, G.
1952. The import of catastrophic mortalities for marine fisheries along the Texas Coast. Jour. Wildlife Management, Vol. 16, pp. 63–69.

Viosca, Percy, Jr.
1927. Flood control in the Mississippi Valley in its relation to Louisiana fisheries. Trans. Am. Fish. Soc., Vol. 57, pp. 49–61.
1938. Effect of the Bonnet Carré spillway on fisheries. La. Cons. Rev., Vol. 6, No. 4, pp. 51–53.

THE EFFECTS OF SEWAGE POLLUTION ON THE FISH POPULATION OF A MIDWESTERN STREAM

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ABSTRACT

Collections of fish were made in Lytle Creek, Clinton County, Ohio, to determine the effect of the partially treated domestic sewage of Wilmington, Ohio, on the fish populations of this stream. The farther the collecting localities were downstream from the plant effluent, the greater were the numbers of species and individuals found. In the septic areas, immediately below the effluent, no fish were observed or collected. Two miles below, in the recovery zone, an average of 1.2 species and 2.2 individuals were taken per collection, with 8 different species represented. Three miles below, also in the recovery zone, 12 species were represented in our collections, with a mean of 1.7 species and 10.8 individuals per collection. In the lower portion of the recovery zone, 4.4 miles below the effluent, 32 species were taken, with a mean of 12.7 species and 197 individuals. In the clean-water zone, 36 species were taken, with a mean of 16.7 species and 294 individuals.

No species could be used as indicators of pollution although several were relatively tolerant of unfavorable conditions. The various species of darters and black bass were highly sensitive and their presence was usually indicative of favorable conditions.

During the winter when the stream flow was at a maximum and the dissolved oxygen was adequate in all sections of the stream, the fish failed to move into the areas they found intolerable during the summer periods of low flow.

INTRODUCTION

Field studies have been conducted for the past 2½ years on Lytle Creek, a small Ohio stream polluted with domestic sewage. These investigations have been directed toward an understanding of the faunal and environmental changes in streams caused by organic pollution and of the resulting damage to aquatic populations. The effects of domestic sewage on some physical and chemical characteristics of the stream and upon the composition of the invertebrate fauna have been discussed by Gaufin and Tarzwell (1952). This paper will treat in particular the effects of sewage pollution upon the species composition, relative abundance, and distribution of the fishes of Lytle Creek.

Description of Lytle Creek

Lytle Creek lies about 45 miles northeast of Cincinnati, in Clinton County, Ohio, and flows into Todd's Fork, which is part of the Little Miami River system. It is a permanent stream, approximately 11 miles long, 3 to 35 feet wide during low-water stages, and drains a watershed of about 27 square miles. The depth of the stream varies from a few inches in the riffles to more than 6 feet in a few pools. The average gradient is 25 feet per mile. The base level of Lytle Creek lies within a meander belt of alluvial origin, the Genessee silt loam. The stream runs through Wisconsin glacial till, except for a short section located about 3 miles from the mouth, where it cuts down to Ordovician limestone.

The principal sources of flow are drainage from adjacent agricultural areas and the effluent of the Wilmington Sewage Treatment Plant, which enters the stream about 7 miles above its mouth. The Sewage Treatment Plant serves the 7,000 inhabitants of Wilmington, Ohio, a non-industrial community. The sewage is treated by a chemical precipitation process, which removes most of the solids and reduces the biochemical oxygen demand of the wastes by about 50 percent. By the time the partially treated wastes are discharged to the stream, decomposition is well advanced, and little or no dissolved oxygen is present in the plant effluent. During normal low flows, the effluent comprises 80 to 90 percent of the total stream volume, causing septic conditions immediately below the outlet.

Lytle Creek is deemed particularly favorable for study because it has only one major source of pollution, is without permanent tributaries below the sewage outfall, and exhibits a wide range of pollutional conditions in its septic, recovery, and clean-water zones.

Six stations representing the different polluted and clean-water zones were selected for routine sampling. Their distances in miles from the mouth of the streams were as follows: upper clean-water zone, 8.7; zone of intermittent pollution, 7.6; septic zone, 5.2; recovery zone, 4.2 and 2.8; and clean-water zone, 1.0. The location of the sewage treatment plant outlet was 7.2 miles from the stream outlet.

Methods

Fish collections were made monthly from May 1950 until July 1951, with the exception of December 1950 and January 1951, when ice cover or flood conditions made seining impossible. Collections were resumed in February 1952 and continued until July of that year.

Samples were taken with two nets, each of ¼-inch-square mesh: one, a straight seine 15 feet long and 5 feet deep; the second, a bag seine 35 feet long and 6 feet deep. At each station, collections were made in the pools and riffles in order to insure capture of species with different habitat preferences. It was possible to sample all stations in one day. Approximately the same amount of time was spent at each station in order to

equalize fishing effort at the various sampling points. However, fish were so few at Stations 5.2 and 4.2 that a longer period was required to establish the presence or absence of fish at those localities. Some of the spring and fall collections were, of necessity, made at periods of relatively high water, during which it was impossible to sample completely some of the deeper areas. The collected fish were preserved and later identified in the laboratory.

At best, the collection methods were only roughly quantitative, and the data obtained are not believed, therefore, to be amenable to rigorous statistical treatment. Yet, as will be seen in later sections of this paper, the observed differences in the fish populations at the various stations were so marked that sampling errors are deemed relatively unimportant, and there can be little doubt of the validity of the major conclusions derived from this study.

Information on the diurnal and seasonal variations of some of the chemical and physical characteristics of Lytle Creek was obtained. Several 24-hour series of observations were made at the various stations during which dissolved oxygen, pH, and temperatures were determined hourly. These data are summarized in Table 1.

A sharp-crested, rectangular, contracted weir and a float-level recorder were placed in the stream about 3 miles above its mouth for the continuous recording of stream flow. During the winter and spring, flows averaged about 6 to 7 cubic feet per second except during frequent floods of 40 cubic feet per second or more. In the late summer and fall, the flow dropped to 1 cubic foot per second.

Abundance of Fish by Species and Number at the Different Stations

The 20 monthly collections yielded a total of 11,235 fish belonging to 6 families and 38 species (Table 2). Not all of these species were found at all times of the year, nor were all species found at any one station.

Not only was the species composition markedly different at the various stations, but the numbers of individuals taken varied also. Fourteen species were taken at Station 8.7, a clean-water area well upstream from the treatment-plant outlet. On the average, 6.5 species and 57 individuals were taken there per monthly collection, with minnows and darters predominant. At Station 7.6, which is a short distance above the treatment plant, 9 different species were collected; the mean number of species and individuals taken per trip were 3.9 and 30, respectively. Various minnows and the white sucker were most abundant. It is suspected that the population in this area is adversely affected by street drainage from Wilmington and periodic leakage of raw sewage from siphons transferring wastes under the stream. This slight pollution, may have repelled some of the more sensitive species resident at Station 8.7.

No fish were ever taken or observed at the sewage outlet, Station 7.2,

TABLE 1.—*The maximum and minimum dissolved-oxygen content (p.p.m.) and water temperature (°F.) at stations in recovery and clean water zones of Lytle Creek*

Station[1]	Item	Dates of hourly sampling over 24-hour period								
		April 24 1951	May 1 1951	May 9, 10 1951	June 28, 29 1951	August 15 1951	August 22, 23 1951	February 22, 23 1951	June 19, 20 1952	July 22, 23 1952
5.2	Temperature Maximum	60.5	76	70	80.5	80	75	41	....	....
	Temperature Minimum	54	65	59	77	71	61	34	....	....
	Oxygen Maximum	12.4	19.1	19.4	11.6	7.3	6.9	11.9	....	....
	Oxygen Minimum	5.4	0.8	2.9	0.2	0.0	0.2	8.2	....	....
4.2	Temperature Maximum	66	76	....	....	77	71.5	41	77	82
	Temperature Minimum	54	65	....	....	72	55	34	67	71
	Oxygen Maximum	16.4	18.1	....	....	5.4	5.5	12.5	3.0	3.0
	Oxygen Minimum	6.5	1.0	....	....	1.4	2.0	8.6	0.6	0.7
2.8	Temperature Maximum	69	79	....	87	87	80	42	86	91
	Temperature Minimum	54	65	....	72	72	59	32	64	70
	Oxygen Maximum	13.8	14.3	....	10.1	12.3	14.7	13.9	11.1	10.2
	Oxygen Minimum	8.1	1.6	....	3.6	1.6	3.2	10.9	3.8	3.1
1.0	Temperature Maximum	70	....	70	....	....	73	41	....	....
	Temperature Minimum	54	....	58	....	....	65.5	32	67	....
	Oxygen Maximum	13.5	....	14.2	....	....	9.6	13.8	....	....
	Oxygen Minimum	6.9	....	5.2	....	....	5.3	10.7	3.8	3.7

[1] Miles above mouth of stream

or at Station 6.5, in the septic zone, although several species of Diptera and other tolerant insects were found to be abundant there by Gaufin and Tarzwell (1952). In the recovery zone, at Station 5.2, the fish fauna was limited, for on the average only 1.2 species and 2.2 individuals were taken. Although 8 different species were collected here, the occurrence of fish was sporadic, and fish were taken in only 8 of 20 collections. The predominant fishes were the creek chub and the fathead minnow.

At Station 4.2, conditions apparently were still marginal for fish, although the stream bottom and the water often looked relatively clean, indicating that much purification had taken place in the stream mile intervening between Stations 5.2 and 4.2. Here, only 1.7 species and 10.8

TABLE 2.—*Fish species taken at selected stations in Lytle Creek, Clinton County, Ohio, and their relative abundance*

["x" indicates presence of species at station. Superscript numerals indicate relative abundance of species]

Species	Common name	Station[1]					
		8.2	7.6	5.2	4.2	2.8	1.0
Carpiodes cyprinus	Quillback carpsucker	..	..	..	..	x	x
Catostomus c. commersoni	White sucker	x	x^3	x	x^5	x^5	x^{10}
Moxostoma erythrurum	Golden redhorse	..	..	..	..	x	x^8
Hypentelium nigricans	Hog sucker	..	..	..	..	x	x
Campostoma a. anomalum	Stoneroller	x	x	..	x	x^8	x^5
Rhinichthys atratulus	Blacknose dace	x	..	..	x^2	x^{10}	x
Semotilus a. atromaculatus	Creek chub	x^2	x^1	x^3	x^1	x^1	x^2
Pimephales p. promelas	Fathead minnow	x^5	x^2	x^1	x^3	x	x
Hyborhynchus notatus	Bluntnose minnow	x^3	x^4	x	x	x^4	x^1
Phenacobius mirabilis	Suckermouth minnow	..	..	..	..	x	x
Hybopsis a. amblops	Northern bigeye chub	..	..	..	..	x	x
Ericymba buccata	Silverjaw minnow	x	..	..	x	x^2	x^6
Notropis cornutus	Common shiner	..	..	x	x	x^6	x^3
Notropis ardens	Rosefin shiner	..	..	..	..	..	x
Notropis rubellus	Rosyface shiner	..	..	..	..	x	x
Notropis photogenis	Silver shiner	..	..	..	..	x^8	x^7
Notropis deliciosus	Sand shiner	x	..	x	x^4	x	x^4
Notropis spilopterus	Spotfin shiner	..	..	..	..	x	x
Notropis volucellus	Mimic shiner	x	..	..	..	x^7	x^9
Notemigonus crysoleucas	Golden shiner	..	..	..	..	x	..
Ameiurus m. melas	Black bullhead	..	..	x^4	x	x^9	x
Ameiurus n. nebulosus	Brown bullhead	..	..	..	..	x	x
Ameiurus natalis	Yellow bullhead	..	..	..	..	x	x
Poecilichthys flabellaris	Barred fantail	..	..	..	..	..	x
Poecilichthys spectabilis	Orange throated darter	x^1	x	..	x	..	x
Poecilichthys caeruleus	Rainbow darter	..	..	..	..	x	x
Etheostoma b. blennioides	Greensided darter	x	..	..	..	x	x
Boleosoma n. nigrum	Johnny darter	x^4	x	..	..	x	x
Percina caprodes	Logperch	..	..	..	..	..	x
Stizostedion v. vitreum	Walleye	..	..	..	..	..	x
Micropterus dolomieui	Smallmouth bass	..	..	..	..	x	x
Micropterus punctulatus	Spotted bass	..	..	..	..	..	x
Micropterus salmoides	Largemouth bass	..	..	..	..	x	..
Lepomis cyanellus	Green sunfish	x	x^4	x^2	x	x	x
Lepomis macrochirus	Bluegill	x	x	..	..	x	x
Ambloplites rupestris	Rock bass	..	..	..	..	x	x
Pomoxis annularis	White crappie	..	..	..	..	x	x
Percopsis omiscomaycus	Trout-perch	..	..	..	..	x	x

[1] Miles above mouth of stream

individuals were collected per trip and fish were caught in 12 of 20 collections. A total of 12 different species were found at this station with the creek chub, the blacknose dace, and the fathead minnow the most abundant.

In the next 1.4 miles, stream conditions improved greatly. Fish were taken in all collections at Station 2.8. A total of 32 species were observed; the average catch contained 12.7 species and 197 individuals. At Station 1.0, where the stream had recovered from its pollutional load, 36 species were captured and the average collection yielded 16.7 species and 294 individuals.

Pollution and Fish Distribution

As indicated in Figure 1 and Table 3, the species and numbers of fishes increased progressively with distance downstream from the sewage-plant outfall. At Stations 5.2 and 4.2, which are in the upper portion of the

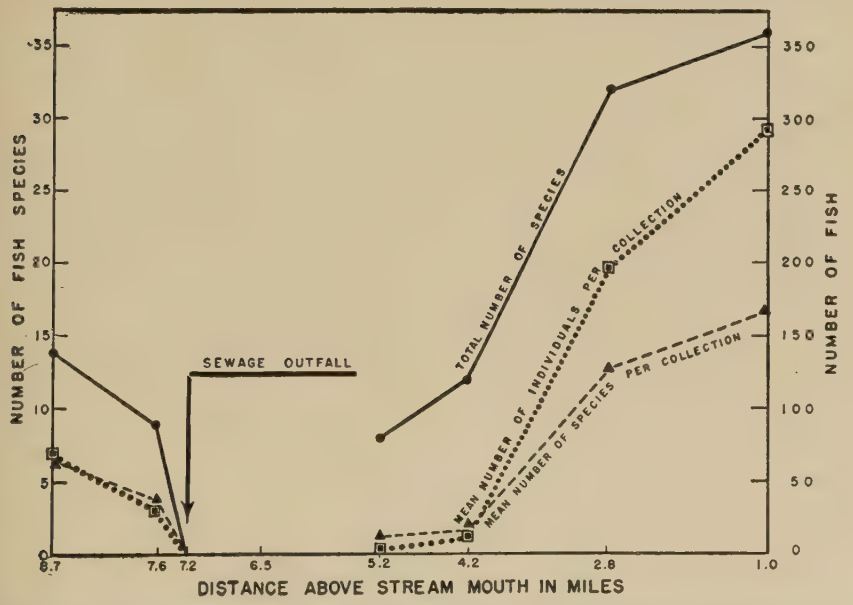

Figure 1.—Total number of fish species, and the mean number of individuals and species taken per collection at different stations in Lytle Creek.

recovery zone, fish were frequently absent or were represented by very few species and individuals, whereas in the lower zone of recovery and the clean-water zone, at Stations 2.8 and 1.0, large numbers of species and individuals were present at all times.

The species composition of the collections was variable even in the clean-water zone. On two occasions, March 1951 and February 1952, 21

species were taken at Station 1.0, whereas only 8 species were collected there in July 1950. There is insufficient evidence for judging whether the difference in the numbers of species taken at different times at any station are related to the migratory habits of the fish or to failure to capture all the species present. It is known that several species of suckers undertake spawning migrations from Todd's Fork into Lytle Creek. The pollution of Lytle Creek has rendered unsuitable large spawning areas of the stream

TABLE 3.—*Number of fish species and individuals taken at the various stations on Lytle Creek*

Item	Station[1]						
	8.2	7.6	Sewage outlet	5.2	4.2	2.8	1.0
Total number of species	14	9	0	8	12	32	36
Range in number of species per collection	4-10	2-8	..	0-5	0-9	8-18	8-23
Mean number of species per collection	6.5	3.9	..	1.2	1.7	12.7	16.7
Total number of individuals	739	420	0	44	216	3,938	5,878
Range in numbers of individuals per collection	19-104	2-146	..	0-10	0-50	23-553	58-572
Mean number of individuals per collection	57	30	..	2.2	10.8	197	294
Number of collections	13	14	..	20	20	[2]21	[2]21

[1] Miles above mouth of stream; location of sewage outlet was 7.2 miles.
[2] One collection was qualitative only, and remaining 20 collections were qualitative and quantitative

which undoubtedly were formerly used by these migratory species, and it has, therefore, an adverse although indirect effect on the Todd's Fork fish populations.

Although Station 8.7 is unpolluted, only 14 species of fish were captured there during the collection period. This figure is less than half the number taken at the lower clean-water station, 1.0. It is recognized (Thompson and Hunt, 1930) that the number of species found in the headwaters of a small stream usually is less than that found in the downstream areas of the same stream. It is possible, however, that the relative scarcity of fish species at Station 8.7 is due in part to the pollutional barrier that prevents fish from moving upstream.

Although certain fishes in Lytle Creek seem to be more tolerant of organic pollution than others, no single species shows a preference for polluted water. Even the tolerant headwater species sometimes found at Stations 5.2 and 4.2 were captured only in small numbers. The creek chub was the most common species in the polluted zones and was often found when no other species were present at these stations. Yet the creek chub was common elsewhere in Lytle Creek and was often predominant even in the downstream cleaner-water zones. Neither the creek chub nor any other tolerant species can, therefore, be regarded as a pollution indicator in the usual sense of the term. The number of species present and their relative abundance are the most important considerations when pollutional conditions in a stream are being evaluated.

No single species, therefore, should be designated as a positive pollution indicator. When careful collection yields only a small number of species which are known to be exceptionally tolerant of pollution, then one may be justified in concluding that the stream station under investigation is a poor habitat for fish. Before that conclusion can be drawn, however, other collections must be made in sections of the stream which are known to be unpolluted, or in adjacent unpolluted streams of the same character, for the purpose of determining the normal population. It is important furthermore, to determine which species are sensitive and are among the first to disappear from waters subject to pollution. In Lytle Creek the various species of darters and black bass seem to fall into this group. Gerking (1947) and Jackson and Henderson (1942) also noted the rapid disappearance of darters in the presence of mixed wastes. In Lytle Creek, at Station 8.7, a clean-water station above the sewage outlet, darters comprised 38 percent of the population; at Station 7.6, where pollution is relatively slight and intermittent, only 4.7 percent of the population consisted of darters, and these fish were frequently absent in the collections. Stations 5.2 and 4.2 which were inhabited only intermittently by small numbers of the relatively tolerant species, yielded only one darter in all the collections. At Station 2.8, which is in the lower portion of the zone of recovery, three species of darters were collected. These darters comprised 1.9 percent of the total collections. They were present intermittently, and were taken in only 10 of 20 collections. At Station 1.0, six different species of darters were collected, and although they were not dominant, comprising only 1.2 percent of the collections, they were found in 12 of 20 collections. No black bass were ever taken at Stations 5.2 and 4.2, and only 4 bass were collected at Station 2.8, whereas at Station 1.0, where the stream had fully recovered from the pollution, 72 black bass were collected. Spawning of black bass seems to have been successful in this area in the spring of 1951.

The presence of black bass and darters is good evidence that organic pollution is not a major limiting factor in an area. However, the use of these species as indicators of favorable stream conditions is limited to specific areas because they do not occur in some types of waters and generally have a scattered geographic distribution. It is perhaps safer, therefore, to rely on the numbers of species of all fish as indicators of the degree of pollution rather than on the presence or absence of a particular species. Even so, careful judgment must be exercised because the number of species normally present in unpolluted streams in different localities with different physical and chemical characteristics varies widely.

Dissolved Oxygen and Fish Distribution

It is an all too common belief that the only deleterious effect of domestic sewage and similar organic wastes on streams lies in the depletion of the dissolved oxygen in the water to a level that results ultimately in the death or dispersal of the normal biota. If the wastes are sufficiently diluted,

so that the biochemical oxygen demand can be satisfied while sufficient dissolved oxygen remains to satisfy the needs of the various organisms present, the pollution with sewage is deemed harmless to aquatic life. Our observations on Lytle Creek indicate that the problem is somewhat more complicated than is commonly believed.

In Lytle Creek during the winter and spring months, stream flow exceeds 6 cubic feet per second, water temperatures are low, and the oxygen concentrations at all stations approach saturation. On the basis of chemical and physical criteria ordinarily employed, the water would be judged to be free from pollution harmful to fish, but the fish did not move during the winter into the areas which were unacceptable to them during the summer. On the contrary, it seemed that the fish found conditions poorer at some of the stations during the winter. Collections made in February and March 1952 failed to yield any fish at Stations 5.2 or 4.2, and only 8 species were taken at Station 2.8. It must be noted, however, that a few darters were present at Station 2.8 in March.

Factors other than the lack of oxygen have made these stations relatively unattractive to fish in winter. Possibly the sewage fungi, bacteria, protozoans, and other pollution-tolerant organisms, which became abundant on the stream bottom as far downstream as Station 2.8 during the colder winter months crowd out those bottom invertebrates that serve as food for some fish. In spite of the presence of the blanket of sewage-tolerant organisms, some fish species remained abundant at Station 2.8; namely, the creek chub and the common sucker, which suggests that food was not a limiting factor for these forms.

During the late spring and throughout the summer and early fall of 1951, the volume of flow fell to about 1 cubic foot per second, while the time required for the sewage effluent to flow from the treatment plant to the mouth of Lytle Creek increased greatly. Water temperatures rose as high as 87°F. and oxygen concentrations became low in the 4-mile section of the stream immediately below the sewage-treatment plant. Definite pollutional zones became established in the late spring and lasted throughout the exceptionally dry summer. Although the oxygen values at all stations sometimes dropped at night to levels which are generally considered to be low, the number of species did not always seem to be influenced by the minimum dissolved-oxygen concentrations. Although the minimal oxygen content at Station 2.8 was sometimes similar to that at Station 4.2, the collections at Station 2.8 always indicated an abundant mixed-fish population whereas the fish were never abundant or varied at Station 4.2. In May and August 1951, for example, the dissolved oxygen at Station 2.8 was as low as 1.6 p.p.m., but large and varied fish populations were collected and observed there. During May 1951, the water at Station 4.2 had a minimum nocturnal dissolved-oxygen content of 1.0 p.p.m.; yet the best collection of the entire series at that station was made at that time. The maximum dissolved-oxygen value observed in daytime during this period was 18.1 p.p.m. These observations may indicate that

fish can survive a rather severe decline of the oxygen content at night, if adequate levels are maintained during the day.

Unquestionably a certain minimum of dissolved oxygen is necessary for the survival of fish, but our findings on Lytle Creek prove that mixed-fish fauna can occur where dissolved-oxygen values are often well below 5 p.p.m. for periods of several hours.

Although the studies on Lytle Creek demonstrate a fairly good correlation between the size and composition of the fish populations and degree of purification of the stream, it is apparent that dissolved oxygen is only one of several factors influencing fish survival in polluted streams. Although the lack of dissolved oxygen in the areas immediately downstream caused fish to be absent during the summer periods of low flow, oxygen lack was certainly no factor in their distribution during the winter months or during periods of high stream flow. Furthermore, a mixed-fish fauna consisting of over 30 species of fish was found at Station 2.8 where the oxygen fell well below the commonly accepted standard of 5 p.p.m. for several hours during the night. However, game fish were found at this station during only a portion of the time and were never as abundant as they were at Station 1.0.

Acknowledgments

The advice, assistance, and constructive criticisms of Public Health Service personnel and others have been of great benefit in this investigation. Rendell Rhoades and Milton B. Trautman of the Ohio Department of Natural Resources and the Ohio State University most obligingly compiled a list of the fish species they had previously collected in Clinton County, Ohio. This list was of great value in confirming our identifications. Dr. Shelby D. Gerking of Indiana University made some valuable and pertinent suggestions. Personnel of the Environmental Health Center who helped with the collections were: W. C. Howard, Donald R. Robertson, Ramon Schulte, Fred Crates, George Paine, Harold Walters, and Earl P. Floyd. The suggestions of Drs. Peter Doudoroff and Clarence M. Tarzwell were of great aid in planning the project and preparing this manuscript.

Literature Cited

Gaufin, Arden R., and C. M. Tarzwell
1952. Aquatic invertebrates as indicators of stream pollution. Pub. Health Rep., Vol. 67, No. 1, pp. 57–64.

Gerking, Shelby D.
1947. The flowing stream—one more world. Purdue Univ. Ext. Ser. No. 64. Proc. Third Ind. Waste Conf., Eng. Bull., Vol. 31, No. 6, pp. 27–33.

Jackson, H. W., and C. Henderson
1942. A study of the stream pollution problem in the Roanoke, Virginia, metropolitan district. Part II-Macroscopic invertebrate and vertebrate faunae. The toxicity of viscose effluent to fishes. Bull. Va. Polytech. Inst., Vol. 35, No. 10, pp. 91–120.

Thompson, D. H., and F. D. Hunt
1930. The fishes of Champaign County—a study of the distribution and abundance of fishes in small streams. Ill. Nat. His. Surv., Bull. 19, Art. 1, pp. 1–101.

EFFECTIVENESS OF ROTENONE IN POND RECLAMATION [1]

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ABSTRACT

The use of rotenone as a means of eradicating fish was studied in 30 ponds distributed throughout Oklahoma, and representing various summer conditions in 1951. In addition, one pond was investigated during the winter.

Over 90 percent of the ponds were thermally stratified and rotenone did not penetrate to the bottom of these shallow ponds (6–13 feet). Agitation with an outboard motor was effective in increasing the penetration of the rotenone. Subsequent to the application, the lower concentrations of rotenone were found in the waters nearest the bottom, and the higher concentrations in the surface waters. This difference was probably due to the limited mixing of the subsurface waters which resulted in an increase of density with depth, and perhaps to greater dissipating power at the lower levels of these chemically stratified ponds. Rotenone in clear waters of low alkalinity (16 p.p.m.) became detoxified in 3 to 6 days depending on the concentration used whereas in clear ponds of high alkalinity (60–284 p.p.m.) detoxification occurred in 1 to 3 days when similar concentrations were used. In turbid waters of high alkalinity, dissipation took from 1 to 2 days longer. Dissipation in a clear-water pond of high alkalinity during the winter took 9 or 10 days. Dissipation occurred from the bottom toward the top. Completeness of the kills was evaluated for 2 to 3 days after treatment. Two to 3 months following application, 18 ponds were re-evaluated. Of these, 16 contained fish and in all but one, only young-of-year were collected.

INTRODUCTION

Reviews on the use of rotenone in fish management (Krumholz, 1948, 1950; Solman, 1950; Smith, 1950; Miller, 1950) have indicated a general lack of follow-up work and controlled experimentation. Such a situation has existed in Oklahoma during a period from 1948 to 1950, when rotenone came to be used extensively in fish management in this state.

The advantage of emulsifiable rotenone (Solman, 1950) over powdered rotenone resulted in the more extensive use of the former which was ap-

[1] A study conducted by the Summer Survey of the Oklahoma Game and Fish Department in 1951.

plied with a power spray designed to pump the desired concentration without previously mixing the poison with water (Clemens, 1952).

The question of appropriate concentration of rotenone for any particular pond in Oklahoma may not always be answered satisfactorily by the recommendations of the manufacturers (0.5 p.p.m.) or of other workers in northern waters (Ball, 1948; Leonard, 1939; Solman, 1950; . . .). However, Solman (1950) reported that in Florida 0.5 p.p.m. of fresh powdered cubé rotenone failed to give a complete kill at 84°F. Brown and Ball (1943) said that the same concentration was ineffective at 48°F.

During the summer of 1951, a detailed investigation of the use of emulsifiable and powdered rotenone was conducted in 30 farm ponds. Such considerations as concentration, vertical distribution, dissipation, and methods of application of the rotenone were studied from the standpoint of total eradication of the fish population.

In this project, concentrations ranged from 0.5 to 3.5 p.p.m. rotenone. Vertical distribution and dissipation of the rotenone were determined by exposing two fish, usually *Notropis lutrensis,* in aerated samples of water collected at various levels. The loss of equilibrium and opercular movements were recorded for the test animals.

General chemical analyses—dissolved oxygen, carbon dioxide, alkalinity, and pH were made for the various depths along with the temperatures and turbidity and in some ponds light penetration as determined with a submarine photometer.

Vertical Distribution of Rotenone

When homothermous conditions existed in Oklahoma ponds during the summer, there was little trouble in getting the rotenone into the bottom waters in sufficient concentrations at depths commonly encountered. Krumholz (1948) and others recognized the problem of obtaining uniform distribution of rotenone at all depths in thermally stratified waters, but this difficulty was not believed to be of consequence in Oklahoma until thermal stratification revealed itself in the majority of farm ponds during the summer.

Krumholz (1948) reviewed several methods that have had reasonable success in the vertical distribution of rotenone. Since it is felt that these methods do not readily assure complete distribution in the bottom water, careful application of the poison with subsequent checks on the efficiency of the method should be conducted to evaluate the eradication of bullheads and other bottom-inhabiting fish.

In thermally stratified shallow impoundments, (up to 10 feet) the question arises as to whether the increased concentrations of rotenone will penetrate the thermocline. In the majority of ponds studied, there is a marked temperature gradient from the surface of the water to the bottom.

Two ponds similar in locality, turbidity, alkalinity, pH, dissolved oxygen, and temperature were treated with different concentrations of rote-

none (Table 1) and its vertical distribution was checked. The first pond, Rattlesnake, was treated with 0.5 p.p.m. emulsifiable rotenone, and water samples collected at the surface and at 4 and 8 feet 3 hours after the application revealed that concentrations of rotenone lethal to minnows were present in the top and middle depths. Minnows were killed in the surface waters in 5 minutes and in the middle depth in 40 minutes, but fish in the samples collected from the bottom waters remained alive. The second pond, Ranch House, was then treated with 2 p.p.m. of emulsifiable rotenone in

TABLE 1.—*Pond characteristics and the rate of kill for minnows in samples of water collected at top, middle, and bottom*

[Rattlesnake Pond had been treated with 0.5 p.p.m. of emulsifiable rotenone 3 hours previously. Ranch House Pond had been treated with 2 p.p.m. of emulsifiable rotenone 1 hour earlier]

Depth (feet)	Temperature (°F.)	pH	Carbon dioxide (p.p.m.)	Bicarbonate (p.p.m.)	Oxygen (p.p.m.)	Time for kill (minutes)
			Ranch House Pond			
Surface	82.5	7.0	2.0	17.0	5.4	4
5	67.0	6.9	4.5	....	1.2	10
10	63.0	6.2	9.0	....	0.0	∞
			Rattlesnake Pond			
Surface	87.0	6.8	4.0	16.0	6.0	5
4	69.0	6.0	13.5	12.0	2.4	40
8	65.0	6.4	9.0	10.0	1.6	∞

an effort to see whether or not the quadrupled rate of application would produce lethal concentrations at the bottom. Tests for rotenone on samples of water taken from the surface and at 5 and 10 feet, 1 hour after application, revealed that minnows were killed in the surface waters in 4 minutes, in the middle waters in 10 minutes, and remained alive in the bottom waters. Similar tests with minnows made on Ranch House Pond for the succeeding 5 days never revealed the presence of rotenone in the bottom waters. The data from the above two ponds suggested that the rotenone did not penetrate appreciably farther when the concentration was quadrupled. It should be pointed out, however, that the concentration of rotenone at 5 feet was apparently much greater than at approximately the same level in Rattlesnake Pond, as evidenced by the much faster kill of the minnows. The main value of increased concentration lies in the fact that the rotenone is held in the surface waters longer as revealed in the dissipation test (Table 2). When surface concentrations remain high, fish find it impossible to escape the poisoned waters by retreating to the lower, non-poisoned levels because the low oxygen concentrations at the greater depths in most ponds forced them to reenter the poisoned areas.

The fact that the rotenone did not settle into the bottom waters in concentrations great enough to kill fish can possibly be explained by inactivation of the rotenone by chemical action in the lower depths and/or

changes in density with increase of depth and lack of agitation of the bottom waters.

In a later section on dissipation, it is shown that the rotenone disappeared first in the water nearer the bottom but it is not clear whether this situation was the result of an originally weaker concentration of rotenone or whether the bottom waters had greater powers of dissipation. The latter is likely since chemical stratification is characteristic of these ponds, but probably both factors were operative.

TABLE 2.—*Pond characteristics and the time for detoxification of rotenone at various concentrations in ponds of low alkalinity*

[The first time figure represents the number of hours from the application to the time when the water was last tested and was toxic. The last figure represents the time when it was next tested and found non-toxic]

Item	Name of pond			
	Rattlesnake	Ranch House	Rough Hollow	North East
Area (acres)	1.1	1.2	0.75	4.1
Alkalinity (p.p.m.)	16.0	17.0	16.0	16.0
pH	6.8	7.0	6.7	7.4
Turbidity (p.p.m.)	20.0	13.0	15.0	20.0
Surface temperature, (°F)	87.0	82.5	89.0	90.25
Rotenone concentration (p.p.m.)	0.5	2	1	[1]0.5
Time for detoxification (hours)	72.5—94	98—146	26—84	70—123

[1] For a depth of 6 feet

To check on the possibility that agitation of the water might increase the penetration of rotenone, an outboard motorboat was run at full speed over the surface of the pond subsequent to the application of the rotenone. The effectiveness of this practice was evaluated by an examination of the change in thermal stratification and by actual tests of rotenone concentrations before and after the agitation. The following temperature data revealed mixing up to at least 6 feet:

	Temperature (°F) at 10:00 a.m. before agitation	*Temperature (°F) at 11:35 a.m. after agitation*
Air	85.25	95.5
Surface	80.25	80.75
3 feet	78.25	80.5
6 feet	64.5	66.25
9 feet	60.0	60.5
12 feet	58.5	58.5

The tests with minnows of water taken at each level revealed that lethal amounts of rotenone penetrated to the depth of 6 feet and that enough reached 9 feet so that the minnows showed distress even though they did not die. It should be noted that in Rattlesnake and Ranch Ponds, where the waters were not stirred by running an outboard motorboat over the surface, the rotenone penetrated to a depth of only 4 or 5 feet.

In some ponds it was not necessary that rotenone penetrate to the bottom waters but only to the waters too low in oxygen to support fish life. If a vertical series of determinations revealed a lack of oxygen at the greater depths, then the rotenone concentration could be calculated on the basis of the volume of water containing oxygen as Greenbank (1941) pointed out.

Dissipation

The study of dissipation of rotenone, that is, the length of time the poison remained in the water in lethal concentrations is important from the standpoint that the rotenone must be held in the water long enough to give a complete kill, and also that one should know when the waters are suitable for restocking. Alkalinity has been reported to be a factor in the effect of rotenone on fish, (Krumholz, 1948; McGonigle and Smith, 1938; Thompson and Bennett, 1939; Vestal, 1943), but differences reported in the time for dissipation (4 to 26 days) were varied and difficult to evaluate since data on temperatures and turbidity were not included. Leonard (1939) reported that certain species of fish are killed faster than others and that the action was faster in acid than in alkaline waters.

Dissipation in ponds with low alkalinities.—Five impoundments similar in size and general physical and chemical characteristics were studied in southeastern Oklahoma (Table 2). These waters had an alkalinity of about 16 p.p.m., a pH of about 6.8, and a summer turbidity around 15 p.p.m.; all were thermally stratified. Periodic checks after treatment for the presence of rotenone in the water revealed a period during which concentrations were great enough to kill minnows.

When a 0.5-p.p.m. concentration of rotenone was applied to the surface of a pond, concentrations lethal to fish remained in the water at least 72 hours but no longer than 94 hours. Rotenone at a concentration of 1 p.p.m. lost its lethal effect on fish sometime between 26 and 84 hours after application, while a concentration of 2 p.p.m. became detoxified between 98 and 146 hours. These data suggest that rotenone remained in the water longer with increasing concentrations but not in proportion to the concentration. Quadrupling the concentration from 0.5 p.p.m. to 2 p.p.m. never more than doubled the time for dissipation.

In each test, minnows were killed more slowly in samples taken at 5 feet than in samples from the surface—a fact which suggests that the rotenone was always in lower concentrations in the deeper levels. It was felt that the rotenone disappeared more rapidly toward the bottom, but for all practical purposes it disappeared from the subsurface waters and surface waters on the same day.

Dissipation in ponds with high alkalinity—clear ponds.—A study of the dissipation in clear ponds with alkalinities ranging from 60 to 284 p.p.m. revealed that 1 p.p.m. of either powdered or emulsifiable rotenone dissipated at summer temperatures to the point that minnows could live in samples of water 1 or 2 days after the application of the poison

(Table 3). Three out of five ponds showed dissipation of an original concentration of 1 p.p.m. rotenone within 24 hours while the remaining two ponds could easily have dissipated the rotenone in approximately the same period of time but tests were not made at appropriate times to detect this. The pond having a concentration of 1.5 p.p.m. rotenone dissipated the poison in about 2 days; one with 2 p.p.m. probably took somewhat longer, although the exact time was not determined. The time for dissipation in these ponds is shorter than the time in ponds having low alkalinities (16

TABLE 3.—*The time for detoxification of rotenone at various concentrations for clear ponds of relatively high alkalinity*
[E = emulsifiable rotenone; P = powdered rotenone]

Item	Name of pond						
	Crump	Readnour	Doenges No. 1	Doenges No. 2	Bar-X	Herne and Tiddle	Dean Cross
Area (acres)	1.8	1.0	1.7	2.1	.86	3.8	1.6
Alkalinity (p.p.m.)	80	80	60	103	101	74	284
pH	8.2	7.7	8.2	8.2	7.9	9.5	8.8
Turbidity	2	7	10	10	10	10	10
Surface temperature (°F.)	78.6	78.2	90	91.6	80.8	86	81.5
Rotenone concentration (p.p.m.)	1(E)	2(E)	1.5(E)	1(P)	1(E)	1(P)	1(E)
Time for detoxification (hours)	0-24	> 45	48-56	22-46	24-47	17-24	8-30

p.p.m.) where 0.5 p.p.m. of rotenone dissipated in at not less than 3 days and 2 p.p.m. in not less than 4 days.

Dissipation in ponds with high alkalinity—turbid ponds.—It appears that turbidity lowers the rate of dissipation. Light is known to accelerate the detoxification of rotenone; Ginsburg (1933) and Gunther (1943) found that rotenone readily decomposed in sunlight, losing its toxic properties in a few days. Moorman and Ruhr (1951), who made a series of tests with dry cubé powder exposed to normal room light for periods up to 31 days, found no significant loss in toxicity. Jones, *et al.*, (1933) found that rotenone-lamp black mixture lost toxicity more slowly than rotenone alone.

In this study, dissipation of a 0.5-p.p.m. concentration of rotenone in Rouse's Pond, which was turbid and had an alkalinity of 76 p.p.m., took from 24 to 41 hours (Table 4). It can be recalled that dissipation of a 0.5-p.p.m. concentration in Rattlesnake Pond, which was relatively clear and had an alkalinity of 16 p.p.m. took from 72 to 94 hours, or from 1 to 3 days longer.

The dissipation of a 1-p.p.m. concentration of rotenone in G. Harrel's Pond took at least 61 hours. The actual time is not known, but from the rate of kill when the last minnow test was made, it is suspected that rotenone disappeared from this pond shortly after the last sample was taken. In clear ponds, detoxification was complete in 2 days and the data suggest that such a condition usually was reached in about 1 day rather than 2.

Dissipation in relation to temperature.—Smith's Pond, Kiowa County, was treated January 15, 1952, with a 2-p.p.m. concentration of powdered derris root and dissipation was tested 2, 6, 9, and 10 days after poisoning. The pond was homothermous, and the temperatures on the first three sampling days were, respectively, 49.6, 50.7, and 43.2 °F, (no record for the tenth day). The rotenone had not disappeared on the ninth day, but

TABLE 4.—*The time for detoxification of rotenone at various concentrations for turbid ponds of high alkalinity*

Item	Name of pond		
	Rouse	G. Harrel	Wades
Area (acres)	1.6	0.24	1.0
Alkalinity (p.p.m.)	76.0	135.0	80.0
pH	7.8	7.7	8.1
Surface temperature (°F.)	79.2	80.5	85.75
Turbidity	45	25	21
Rotenone concentration, (p.p.m.)	0.5(E)	1(E)	1(E)
Time for detoxification (hours)	24-41	> 62	> 20

no toxicity could be detected at 5:00 p.m. on the tenth day. The 2-p.p.m. rotenone, therefore, remained in the water about 6 to 7 days longer (or at least twice as long) than the same concentration of rotenone in ponds of similar turbidity and alkalinity during the summer (Table 3). It seems that during the winter the longer time for dissipation is largely a factor of temperature.

Water samples collected at top, middle, and bottom depths in Smith's Pond at 50°F. revealed that the rotenone dissipated a day sooner in the middle water than in the surface waters. There was indication of a similar situation in the work done during the summer in Rattlesnake and other ponds although the rotenone disappeared from the middle waters within a day of the upper waters, thus making the dissipation from top to bottom practically uniform. Similar effects have been reported in northern waters, (Brown and Ball, 1943).

Effective Kill

There can be no certainty of a complete kill unless a pond is drained, but the term is used here when the kill was estimated to be complete from the following evaluations: (1) minnows could not live in samples of water taken at various levels from top to the bottom; (2) no indications of live fish, especially along the shore, could be detected; (3) recently killed fish were not found on the days subsequent to the application; (4) seining and netting operations revealed no fish; (5) no fish could be obtained by further application of rotenone. No one test should be accepted alone as evidence of complete kill, but as many as possible should be used to confirm an absence of fish. The best evaluation of a complete kill would come from draining. Two ponds at Stringtown were drained and fish were found

in both. The kill was thought to have been complete in one but incomplete in the other (Table 5).

On the basis of observations made during daily visits for 2 to 5 days following treatment, the kill was estimated in each pond. Two to 3 months later, opportunity to revisit 18 of the ponds made it possible to check the previous evaluation of the kill. At this time 16 of the 18 ponds contained fish (Table 5). However, in 2 of the 16, only a single *Gambusia* could be obtained from extensive seining operations. The fish were nearly all killed,

TABLE 5.—*Evaluation of the kill in 18 ponds, 2 to 4 days and 2 to 3 months after the application of rotenone*

[The species of fish present before and after the kill are indicated as follows: 1—green sunfish; 2—bluegill; 3—redear sunfish; 4—longear sunfish; 5—orangespotted sunfish; 6—white crappie; 7—black crappie; 8—largemouth bass; 9—channel catfish; 10—black bullhead; 11—yellow bullhead; 12—fathead minnow; 13—plains killifish; 14—golden shiner; 15—red shiner; 16—bluntnose minnow; 17—mosquitofish; 18—warmouth. C—complete kill; I—incomplete kill; D—doubtful kill; N.S.—kill not studied]

Name of pond	Estimated kill		Species of fish	
	2-4 days after treatment	2-3 months after treatment	Before treatment	2-3 months after treatment
Readnour	N.S.	I	1, 2, 8	1
Cross	I	I	1, 2, 3, 6, 8, 9, 10, 12, 13	1, 13
N. W. Stringtown	N.S.	I	1, 5, 14	1
N. E. Stringtown	I	I	1, 14, 15	1
Rough Hollow	C	I	1, 8, 14, 15	1
Wade	C	I	1, 10, 12	17
Wright	C	I	1, 2, 6, 8, 9, 15	17
Rouse	I	I	1, 3, 5, 6, 8, 9, 10, 15	1, 10, 15
Crump	I	I	2, 3, 7, 8, 15	2
McCarley	N.S.	I	1, 2, 3, 4, 6, 8, 9, 10, 18	2, 14, 15, 18
Atkin	I	I	1, 6, 9, 10	1, 10
Shepherd	I	I	6, 9, 10, 12, 14, 15	1, 12, 17
Doenges No. 1	C	I	1, 5, 10, 14	1, 10
Doenges No. 2	D	I	1, 2, 3, 7, 8, 10, 14	2, 10
Ranch House	C	I[1]	1	1
Rattlesnake	I	I[1]	1, 5, 9, 10, 14, 16	1
Herne and Tiddle	D	C	1, 2, 5, 8, 10, 11, 13, 15	....
George Harrell	C	C	1, 10	....

[1] Drained to check kill

therefore, in four ponds. One of these four, Herne and Tiddle Pond, received two applications of rotenone in close sequence; the first treatment of 1 p.p.m. led to an incomplete kill, but the subsequent treatment at a concentration of 2 p.p.m. rotenone apparently was effective in killing the remaining fish. In the 16 ponds that contained fish the kill had been previously evaluated as follows: 7 ponds, incomplete; 5, complete; 1, doubtful; 3, kill not studied. When the different means of judging kills were reviewed, it was found that recently killed fish or evidence of fish movement on the days subsequent to the treatment were the best and most convenient methods of evaluation. Of course, it must be remembered that this statement holds for summer temperatures only, for during the winter the killing of fish is prolonged from one to several days. Ball (1946) recorded a complete kill in only 18 of 33 lakes treated with rotenone. Twelve of the 18 lakes were trout lakes, and to the date of his paper, 6 of the 12 lakes had become repopu-

lated with warm-water fish, even though only trout were stocked and live bait was prohibited. Ball did not give his criteria for a complete kill.

Among the fish that were taken by seine 2 to 3 months after treatment were many green sunfish, a lesser number of bullheads, and occasionally, mosquitofish, plains killifish, red shiner, warmouth, and fathead minnows. Moorman and Ruhr (1951) found that green sunfish were somewhat less susceptible to poisoning than were orangespotted sunfish and also pointed out that bullheads managed to recover after showing definite response to the rotenone. Only one green sunfish was observed to recover after having shown symptoms of poisoning.

Fish previously found in ponds before poisoning but which were not detected at the time of the re-evaluation 2 to 3 months later were: largemouth bass, white crappie, redear sunfish, black crappie, channel catfish, orangespotted sunfish, and longear sunfish. In every pond but one, the fish that were found were young-of-year, usually less than 1 inch long.

The presence of fish in some of the treated ponds at this later date may represent an incomplete kill—that is individuals escaped the poison either as fish or fish spawn. Leonard (1939) conducted an experiment on trout eggs, which suggested that the eggs were unaffected by the rotenone but when they hatched the small fry quickly died. Other ponds may have contained fish as the result of subsequent stocking either deliberate or more probably from the washing down into the pond of small fish from the pools above. Stocking by humans might have happened but the preponderance of green sunfish discounts this as a major possibility. Access of fish to the pond is probable since the green sunfish is commonly found in streams and could have entered the pond during periods of runoff.

If we accept incomplete kills as explanation of the presence of the fish in the fall, and this possibility must be conceded, then a number of circumstances might have existed, such as: (1) poor penetration of the rotenone; (2)in sufficient concentration of the rotenone; (3) incomplete dispersal of the rotenone through the surface waters, especially in weed beds; (4) too rapid dissipation of the rotenone. All these factors have been discussed previously and their importance stressed.

Recommended Procedure for Application of Rotenone to Farm Ponds

From the above considerations, it seems that the terms complete kill or total eradication have been improperly used in the past surveys of Oklahoma farm ponds that were thermally stratified. Careful procedure in using rotenone when a complete kill is attempted would be as follows:

1. Determine whether a thermocline is present (rotenone applied to surface waters does not penetrate effectively into the thermocline).

2. If the pond is thermally stratified determine the dissolved oxygen concentration at the various depths to indicate the levels where fish can live and thus the depth to which rotenone must penetrate. If dissolved

oxygen is not found at all depths, the calculations for the concentration of rotenone can be made on the basis of the depth to which oxygen is found, as a greatest depth of the pond. This point has particular significance in the larger ponds where the cost of the rotenone is an important item.

3. Employ appropriate techniques to assist in the vertical distribution of the rotenone. Dragging a weighted bag of powdered rotenone at the required depth, or pumping the rotenone down through a hose are perhaps two of the better methods (Krumholz, 1948). Such a practice, however, does not assure complete distribution through the lower strata of water. The agitation of the surface waters with an outboard motor is significantly helpful. One half hour per half-acre was found sufficient to assure mixing down to at least 6 feet.

4. Be sure that rotenone is applied thoroughly to all shoreline waters and vegetated areas since the rotenone does not readily disperse in the quiet water and small fish in these habitats may escape the poison.

5. Check the penetration of the rotenone into the deeper water by drawing water from different depths and observing its effect on minnows. This water may have to be aerated before the test is made if it is devoid of oxygen.

6. Water at all depths in which fish live should be provided with a concentration of rotenone so that toxic conditions remain in the water for an adequate period, at least 3 days and possibly 7 to 10 days if spawn is to be killed.

7. The following concentrations are recommended as a minimum for emulsifiable rotenone, (slightly higher for powdered):

a. Low-alkalinity ponds—1 p.p.m.

b. High-alkalinity ponds (60 p.p.m. and up): if turbid—(Secchi disc value at 6 inches)—1 p.p.m.; if clear—2 p.p.m.

8. Make duplicate applications several days apart to avoid survival of fish eggs, if the poisoning is to be done during the summer some 2 to 3 months prior to stocking.

9. Carry out treatments in late spring and early summer just prior to onset of weed growth or perferably in late fall immediately before restocking and when the water temperatures are more favorable.

10. Pools above the pond should be poisoned. A good rain may be responsible for restocking the pond with fish found in the pools above.

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Literature Cited

Ball, Robert C.
1948a. A summary of experiments in Michigan lakes on the elimination of fish populations with rotenone, 1934–1942. Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 139–146.
1948b. Recovery of marked fish following a second poisoning of the population in Ford Lake, Michigan. Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 36–42.

Brown, C. J. D. and Robert C. Ball
1943. A fish population study of Third Sister Lake. Trans. Am. Fish. Soc., Vol. 72 (1942), pp. 177–186.

Clemens, Howard P.
1952. An aid in application of emulsifiable rotenone in pond reclamation. Prog. Fish-Cult., Vol. 14, pp. 32–33.

Greenbank, John
1941. Selective poisoning of fish. Trans. Am. Fish. Soc., Vol. 70, (1940), pp. 80–86.

Ginsburg, J. M.
1933. Rotenone: Its insecticidal value. N. J. Agric. Exp. Sta., Circ. 273. 2 pp.

Gunther, F. A.
1943. Effects of oxygen and sunlight and decomposition of rotenone in spray mixtures. Jour. Econ. Ent., Vol. 36, pp. 273–281.

Jones, Howard A., W. A. Gersdorff, E. L. Gooden, F. L. Campbell, and W. N. Sullivan
1933. Loss in toxicity of deposits of rotenone and related materials exposed to light. Jour. Econ. Ent., Vol. 26, pp. 451–470.

Krumholz, Louis A.
1948. Special article. The use of rotenone in fisheries research. Jour. Wildlife Man., Vol. 12, pp. 305–317.
1950. Some practical considerations in the use of rotenone in fisheries research. Jour. Wildlife Man., Vol. 14, pp. 415–424.

Leonard, J. W.
1939. Notes on the use of derris as a fish poison. Trans. Am. Fish. Soc., Vol. 68 (1938), pp. 269–279.

McGonigle, R. H., and M. W. Smith
1938. Cobequid hatchery—fish production in Second river, and a new method of disease control. Prog. Fish-Cult., Vol. 38, pp. 5–11.

Miller, Richard B.
1950. A critique of the need and use of poisons in fisheries research and management. Canadian Fish-Cult., Vol. 8, pp. 30–33.

Moorman, Robert B. and C. E. Ruhr
1951. Suggestions for improving the collection of fish with rotenone. Prog. Fish-Cult., Vol. 13, pp. 149–152.

Smith, M. W.
1950. The use of poisons to control undesirable fish in Canadian fresh-waters. Canadian Fish-Cult., Vol. 8, pp. 17–29.

Solman, V. E. F.
1950. History and use of fish poisons in the United States. Canadian Fish-Cult., Vol. 8, pp. 3–16.

Thompson, D. H., and G. W. Bennett
1939. Lake management reports 2. Fork lake near Mt. Zion, Illinois. Ill. Nat. Hist. Surv., Biol. Notes, Vol. 11, pp. 1–24.

Vestal, Elden H.
1942. Rough fish control in Gull Lake, Mono county, California. Cal. Fish and Game, Vol. 28, pp. 34–61.

THE 1944 YEAR CLASS OF LAKE TROUT IN SOUTH BAY, LAKE HURON

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Abstract

The 1944 year class of lake trout (*Salvelinus namaycush*) supported a significant sport fishery in South Bay, Manitoulin Island, over the years 1948 to 1950, inclusive, at a time when that species was absent in any numbers in adjoining Lake Huron. The evidence from tagging indicates that this population of lake trout in South Bay was a resident one. These trout reached a length of 20 inches and a weight of 4 pounds as age-group VI. Growth data based on scale reading are presented for age-groups II to VII and confirmed by observations on marked fish. Estimates of the size of the lake trout populations and of the survival of groups marked in different years were made by fin clipping and tagging through the years 1948 to 1951. The population was estimated to consist of some 21,000 fish in 1948 and to have fallen to 600 fish in 1951, the highest mortality rates coming after 1949. Only 3,124 lake trout were recorded as removed by angling during that period and it is believed that the creel census covered more than 90 percent of the fishery. It is suggested that the sea lamprey (*Petromyzon marinus*) was responsible for the death of most of the remainder of the population and evidence is presented to show that the incidence of scarred fish greatly increased in the years when the estimates of mortality were also high.

When the Ontario Department of Lands and Forests initiated its experimental fishery in 1947 in South Bay, a 30-square-mile arm of Lake Huron extending into the south-east corner of Manitoulin Island, it was found that small lake trout, *Salvelinus namaycush* (Walbaum), were present there in numbers. Approximately 1,000 specimens with an average length of 14.7 inches taken incidental to other operations were examined in that year. Most of these fish were caught by the teeth in gill net of 4½-inch mesh (extension measure) or larger. In view of the drastic decline of the lake trout fishery in Lake Huron, this find was somewhat of a surprise and special attention was paid to this population in subsequent years. It transpired that this population was in the main made up of the representatives of a single year class, the hatch of 1944.

The data of Table 1 essentially cover the period 1947–1952 since the catch of lake trout by angling in the years within that period not tabulated

has been negligible. Over the past 6 years the yield from the 1944 year class has been of the order of 5 times as great as that of the year class of 1943 and 10 times that of the 1945 year class. Yields from all other classes likely to contribute to the fishery within the period under consideration have scarcely been of any significance. Strong evidence was found in 1952 to indicate that this dearth in production persisted at least until the spawning of 1948. Among 97 lake trout hatched since 1944 which were taken

TABLE 1.—*Estimated yield (numbers of fish) of various year classes of lake trout to the sport fishery of South Bay in the years 1948-50*

Year of capture	Year class						
	1940	1941	1942	1943	1944	1945	1946
1948	6	0	34	350	629	28	0
1949	0	0	11	166	1,345	125	8
1950	0	0	0	6	365	51	0
Total	6	0	45	522	2,339	204	8

in experimental nets in 1952 only 33 did not have the adipose clipped, the mark put on plantings of yearlings introduced into South Bay in 1949 and 1951.

METHODS

The Department of Lands and Forests has maintained a field station on South Bay since 1947 at which extensive experimental fishing is carried on largely by traps and pound nets. A nearly complete creel census of South Bay has also been taken during the same time. Most of the game fish taken in the experimental fishery have been marked and released. Marking has been by fin-clipping and by ½- by ¼-inch celluloid tags. The tags were attached by monofilament nylon just behind the base of the first dorsal fin ray. Retention of these tags by the lake trout appears to be good. With the exception that the adipose was removed completely in 1947, fins were clipped by removing the distal half only which then regenerated more or less completely but the mark could still be recognized. By using the fin-clipping together with tagging it was estimated that only about 10 percent of the tags were lost over the first winter after attachment. The tags, however, do tend to be torn off if the fish are taken in gill nets. A few tags were fixed with silver wire instead of nylon; the wire appeared to favor healing but no thorough comparison was made.

Trout were marked by fin clipping alone in 1947 and 1948, by a combination of tagging and clipping in 1949 and by tagging alone in 1950 and 1951. The fish were mildly anaesthetized by placing them in a tub containing approximately 5 percent urethane solution until they became sluggish enough to be easily handled. They were then tagged, measured to the nearest half-inch, and a sample of scales taken from the right side. Recap-

tures were also measured and a sample of scales taken from their left side. The scales were read as impressions on cellulose acetate.

The creel census was carried on by personal interviews and by the use of forms similar to those described in Fry and Kennedy (1937). It is estimated that the coverage of the lake trout fishery was at least 90-percent complete. A substantial fraction of the anglers' catch was measured and examined for marks.

Acknowledgments

The data presented here are the fruit of the effort of a considerable number of workers who have been in the employ of the Research Division of the Ontario Department of Lands and Forests. Chief among these are Messrs. J. C. Budd and J. M. Fraser who were responsible for most of the tagging program and other field work. Mrs. A. Browne (née L. C. Craigie) made age determinations from scales. Mr. D. Teichroew acted as consultant and to some extent as computor in the statistical work. He set up the system for recording the data on I.B.M. punch cards. Messrs. J. M. Fraser and K. K. Irizawa punched and listed the data. Mr. L. M. Morrison computed most of the Schnabel-type population estimates.

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Movements of Lake Trout in South Bay

The lake trout population in South Bay appears to be essentially confined to that body of water. The maintenance of a population there at a time when very few could be taken in the adjacent waters of Lake Huron is indirect evidence of this isolation. More direct evidence is afforded by our tagging data. Of some 3,700 lake trout tagged in South Bay in the years 1949 to 1951, only 3 have been recovered in outside waters. This result is in sharp contrast to that obtained from the whitefish released over the same period. Approximately 10 percent of these have been taken by outside fishermen, chiefly in Georgian Bay and the area off the west coast of the Saugeen Peninsula.

South Bay, which is connected to Lake Huron only through a narrows 700 feet wide, is divided into two very unequal sections by a second more moderate constriction about one quarter of the distance from the mouth to the head of the bay. The outer basin is relatively shallow (7 fathoms) and is not occupied by any appreciable number of lake trout in the summer months. At that time the trout are chiefly to be found at depths below the thermocline in the inner basin, which has an extensive area of deep water extending down to 30 fathoms. The lake trout are typically taken by trolling in water of 8 fathoms and deeper in the regions indicated in the legend of Figure 1.

The best evidence for a virtually complete retreat of the lake trout population to the inner basin for the summer months is afforded by the origin of the tagged fish taken by anglers. These tagged fish were released about a month previous to the main sport fishery from various pound

nets located at points along the shore from just inside the mouth to well within the inner basin. The locations of these nets are indicated in Figure 1. As Table 2 shows, the contribution of each net to the sport fishery in 1949 was almost precisely in proportion to the number of fish released from it. Thus the trout tagged near the mouth of the bay (Net A) are at least as likely to return to the deep water where the sport fishery is pursued as are those tagged well toward its inner end (Net H).

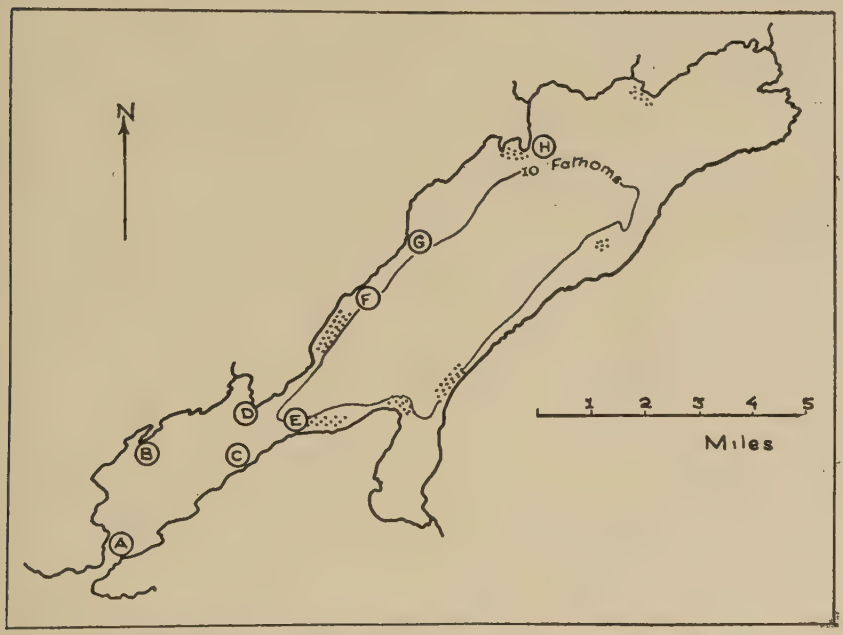

FIGURE 1.—Map of South Bay. The stippled areas approximate the positions of the known spawning beds and the letters indicate the positions of the pound nets fished in 1949. Most of the lake trout trolling is done in the region of the 10-fathom contour west and south of Net G.

The origin of the 1949 tags recaptured in the nets in 1950 affords further but less direct evidence to reinforce the belief that the South Bay population of lake trout is a resident one. These tags, as in the angling of 1949, were taken essentially in proportion to the numbers released from each net in 1949 (Table 2). Experimental fishing in Lake Huron adjacent to South Bay indicated that mortality of lake trout came earlier there than in South Bay itself. Therefore, it would be expected that if fish from the outer basin had emigrated in numbers for the summer, they would have suffered a greater mortality than that fraction of the population which remained in South Bay. In such a case the 1949 releases from the outer nets would not have been as well represented in the 1950 catches as fish from the nets in the inner basin.

The spring movement of the lake trout was followed best in 1949, a year when the weather permitted the pound nets to be set early and which was also the year when peak numbers of lake trout were available for capture. The lake trout apparently move about actively at this time since only 44 of 369 recaptures in the pound nets were retaken in the same net as that from which they had been released. These figures represent a ratio of 1:8 which is the expected ratio for complete mixing since 8 nets

TABLE 2.—*Recovery of tags released from various pound nets in 1949 in comparison with the numbers released*

Item	Net							
	A	B	C	D	E	F	G	H
Number of tagged fish released	301	421	164	47	1,029	39	425	492
Contribution to 1949 sport fishery	29	35	15	3	91	0	37	46
Ratio: $\frac{\text{contributed}}{\text{released}}$	0.096	0.083	0.092	0.064	0.089	.....	0.087	0.093
Contributed to 1950 net fishery	14	24	7	5	41	4	21	29
Ratio: $\frac{\text{contributed}}{\text{released}}$	0.046	0.057	0.043	0.106	0.040	0.103	0.057	0.059

were fished. However, the similarity of the observed ratio to that expected on the assumption of complete mixing is probably no more than coincidence because 26 of the 44 trout recaptured in the same net as that from which they were released were taken in a single net (E). Thus it seems likely that certain nets in the outer basin, in particular Net C which retook none of its own releases, were fishing a population which moved away from their vicinity as the season advanced. It is not so certain that the lack of "self-recaptures" in Net D and the low number of them in Net F can be ascribed to the same cause for these nets were set much later in the season and many marked fish had been released from other nets before these nets began to make a contribution of their own tags.

The movement is predominantly into the deeper water of the inner basin, since 315 of the total of 369 recaptures were taken by nets E to H set adjacent to this water. Among these 315, 99 came from Nets A to C in the outer basin. Since more nets were set early in the outer basin this trend is influenced by the length of time the nets were fishing, but such an effect can be largely removed by considering only fish marked on or after May 26. These data are also given in Table 3. The trend into the inner basin is even more marked in these later releases, 112 of a total of 134 marks being recaptured there.

The contribution of fish marked after May 25 from Nets A to C in the

outer basin to the net catch in the inner basin was decidedly less in proportion to the numbers released than was the contribution from earlier marking. (12 of 475 as opposed to 99 of 423). On these grounds it might be suspected that the fish marked in the outer basin towards the end of the season went out into Lake Huron instead of returning in the inner basin. This, however, does not appear to be true. Detailed examination of angling returns showed that not only were the returns from each net represented in proportion to the releases as is mentioned above, but that the

TABLE 3.—*Summary of recaptures of tagged lake trout in the 1949 pound-net fishery*
[The first number of each pair refers to releases before May 26, the second to subsequent releases. The dates at the head of the columns are the dates of the first lift from each net. A blank indicates the net was not being fished]

Net in which fish were recaptured	Net at which fish were tagged and released															
	A May 11		B May 12		C May 11		D June 4		E May 16		F June 8		G May 26		H May 24	
A.....	3	1	5	1	1	0	..	0	2	4	..	0	0	3	0	3
B.....	3	3	2	0	3	0	..	1	1	2	..	0	0	2	3	0
C.....	0	0	1	0	0	0	..	0	2	0	..	0	0	0	0	0
D.....	0	0	2	0	1	0	..	0	3	0	..	0	0	1	0	1
E.....	10	4	14	4	5	1	..	0	14	12	..	1	1	16	9	23
F.....	1	0	2	1	3	0	..	0	3	12	..	3	1	1	2	9
G.....	5	0	10	0	14	1	..	0	32	5	..	0	3	2	7	7
H.....	10	1	13	0	12	0	..	0	31	6	..	0	0	0	1	3

contributions from fish tagged before and after May 26 in the nets of the outer basin also corresponded to the numbers released. The ratio of tags in the anglers' catch that were marked in nets A to C before May 26 to those marked subsequently was 35:37; the numbers released had a ratio of 475:423.

The explanation of the discrepancy appears to be that the pound nets sample only shallow water; the tunnel depths were less than 20 feet except in Net F where it was 30 feet. The fish marked later retreated more promptly to the deeper water than those marked early and were thus not sampled by these nets on their return to the inner basin.

The lake trout return to shallow water in October and spawning takes place on broken rock along the shores of the inner basin. The locations of the known spawning beds are indicated in Figure 1. The spawning run was sampled in 1950, the first year in which members of the 1944 year class could have been expected to become mature. There were 143 fish taken in this sample of which 47 had been tagged. This high ratio of tagged to untagged fish appears to indicate not only that the South Bay population spawns within the bay, but also that the spawning run is not diluted by the entry of outside fish.

The lake trout do not appear to return in numbers to the outer basin until late winter. When the bay was fished commercially in winter in the first quarter of the century, all the fishing for lake trout was in the inner

basin or in the narrows leading to it. Our limited winter fishing operations show the same distribution of trout. For example, no lake trout were caught in the outer basin in October 1950 nor on the shoal just outside the mouth of the bay. Fishing by gill nets of 4½-inch stretched mesh for burbot, *Lota lota,* which was carried out in the winters of 1949–50 and 1950–51, yielded but few lake trout. These nets, which were set mainly in the outer basin and in the narrows between the basins, caught a total of 12 trout in 1950 and 10 in 1951. To catch these fish, approximately 5,000 feet of net was fished continuously from February 11 to March 21 in 1950 and 3,200 feet in 1951 from March 7 to March 15, with half that amount fished further until April 2. None of the trout taken in 1950 was captured before March.

Growth

A summary of the age-length relationships found for the South Bay lake trout during the years when the 1944 year class was dominant is given in Table 4. There the mean lengths at the various ages in the different years are given separately for the net samples and for lake trout taken by angling together with a grand mean of all the subsamples at each age.

Net selection does not appear to have strongly influenced the mean length at a given age at least beyond age-group IV. In 1947 and 1948 when the fish of age-groups III and IV were abundant, most of the specimens were accidently snarled in 4½-inch gill nets and thus were not selectively taken. Fish taken by angling of age-group III were considerably larger than those in the net sample but were so few that they had little effect on the grand mean. There is close agreement between the lengths of the samples of older fish taken by net and by angling. There are some discrepancies at age IV but these are not large.

The age-length relationship as assessed by scale readings is plotted as a solid line in Figure 2. Plotted as dots on the same graph are values for growth rates determined from the measurement of tagged fish recaptured 1 and 2 years after release. The use of a 12-month interval between the points seem to be quite justified because values for recaptured fish used in this comparison are only for those taken in the net fishery, which is largely concentrated in the spring before the beginning of the current season's growth.

The intraseasonal growth of the population in 1949 could be assessed from the large number of tagged lake trout released in the spring together with those retaken in successive ½-month intervals through the remainder of the summer by anglers. The lake trout appear to grow steadily throughout the summer and add about 1 inch of their total growth increment for the year by mid-September. The total increment for the major year class represented in 1949 (the 1944 year class) until May 1950 was estimated at 1.8 inches. This increment, as the dotted line on the graph suggests, would indicate that the rapid growth observed from June to September probably continued at least until mid-October.

TABLE 4.—*Growth of lake trout in South Bay as indicated by the average fork lengths (inches) of the several age groups*

[Number of specimens in parentheses. The mean weights at the bottom of the table were derived from creel census data except for age groups II and III. The roman numerals indicate number of completed annuli]

Year	Source of sample	Age group							
		II	III	IV	V	VI	VII	VIII	IX
1947	Nets	10.0 (21)	12.6 (110)	16.6 (130)	18.6 (142)	26.7 (2)	.....	.....	.....
1948	Creel census	.....	15.2 (5)	16.8 (111)	18.0 (62)	21.0 (6)	.....	31.0 (1)	.....
	Nets	.....	11.5 (22)	15.7 (146)	18.6 (65)	19.3 (3)	27.0 (1)	.....	29.0 (1)
1949	Creel census	.....	14.2 (5)	16.5 (66)	18.9 (697)	20.8 (84)	24.8 (3)	.....	.....
	Nets	.....	.....	17.4 (97)	18.9 (579)	20.0 (26)	.....	.....	.....
1950	Creel census	.....	.....	.....	19.0 (23)	20.5 (163)	22.2 (2)	.....	.....
	Nets	.....	.....	15.8 (4)	18.8 (206)	20.7 (684)	22.4 (32)	.....	.....
Mean length		10.0	12.7	16.5	18.8	20.6	22.7	.....	.....
Mean weight (ounces)		6.7 (21)	11.6 (32)	34.2 (342)	45.9 (832)	61.8 (249)	108 (5)	.....	.....

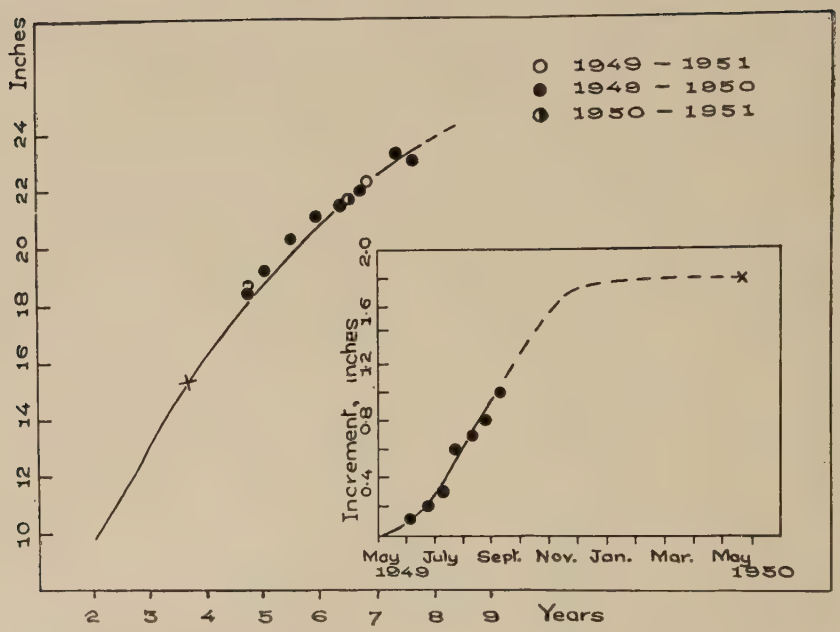

FIGURE 2.—Growth curves for South Bay lake trout from scale readings and recovery of marked fish. The line in the main graph is the age-length relationship taken from Table 4; the points are growth rates determined from marking and recapture. These points were fitted to the curve as follows. The average length at release of a given sample of fish was placed on the curve as determined by scale reading and then the length at recapture plotted on the ordinate occurring one year later. Thus the mean length of the fish tagged in 1949 and recaptured in 1950 that were under 16 inches when released was 15.3 in. This length occurs at 3.7 years on the length-age curve and is indicated in the figure by a cross. The average length of this sample on recapture in 1950 was 18.8 inches. This point, the lowermost of the solid dots, was therefore plotted at 4.7 years. All the other points have been placed similarly but their points of origin have not been marked to avoid complicating the graph. The inset shows growth of marked fish released and recaptured in 1949.

SURVIVAL OF SOUTH BAY LAKE TROUT

Population estimates based on marking and recapture must always be viewed with reservations, particularly because of the stratification which occurs in the distribution of the population itself and that which arises in the sample from the selectivity of the nets. However, at least in a qualitative way, the course of the mortality which removed the 1944 year class from South Bay appears clear from marking data. In 1948 and 1949, conditions were favorable for large-scale sampling, and population estimates of reasonable reliability were probably obtained.

The first marking was done in 1947 when approximately 500 lake trout were released. These fish were marked by clipping the adipose fin. Only

6 of these releases were recaptured in that year which led us to wonder whether many of them survived handling. However, in subsequent years it is estimated that about 100 of them were recovered either in our samples or by anglers. Since it is not certain that this mark was consistently recognized on subsequent handling, the 1947 marks have not been considered in further work.

Marking in 1948 was done by clipping the right pelvic fin. Approximately 1,850 lake trout were marked in this manner. The number of fish so marked in the fishery up to July 14, 1948 was 1,823 of which 112 were recaptured in the same nets during the same period. A Schnabel-type estimate (De Lury, 1951) based on the data from this fishery gave a value of 19,500 for the population. In addition, Teichroew (personal communication) made a Petersen estimate based on the size of the total catch reported by anglers. This estimate yielded a value of 23,000 for the population (Table 5).

The agreement between the estimates based on data from nets and from angling indicates that the populations vulnerable to each fishery were of similar magnitude and presumably that the estimate is of the total population of lake trout large enough for capture by these methods. The high estimate for the net fishery is another indication of the active ranging of the lake trout during their spring period in shallow water.

The most extensive marking was carried out in 1949 in which year some 3,000 marked lake trout were released from the nets. The majority of these fish were tagged as well as fin-clipped and records were kept of the length of the individuals on release and on any subsequent recapture. For this year, it has been possible to stratify the estimates by size. The estimate for the population vulnerable to the pound nets was 14,000 and for that vulnerable to the sport fishery 20,000. Some recruitment into each fishery had no doubt occurred since 1948, but even taking this into consideration the population does not appear to have suffered any unusual mortality between 1948 and 1949.

Mortality among the older fish can be assessed further by estimating the number of 1948 marks extant in 1949. Again two estimates can be made, a Schnabel-type estimate during the net fishery and a Petersen-type from the creel-census data. The Schnabel estimate based on the fishery up to June 14 gave a value of 1,350 for the 1948 marks still extant. The estimate based on the angling returns gave a value of 1,276. This latter estimate was made up as follows. Of a total of 110, 1948 marks seen on anglers' lake trout examined at the laboratory, 41 also bore 1949 marks and had thus been seen in the net fishery. The total 1948 marks seen in the 1949 net fishery was 474, hence, by proportionality, 1,276 fish bearing these marks had survived from the previous year. If the two estimates are given equal weight, approximately 1,300 of the trout with 1948 marks survived until 1949. The maximum number of marks extant at the end of the 1948 fishery was estimated to be 1,750 after allowance was made for fishing mortality in that season. The natural mortality over 1948–49 on this basis, therefore, amounted to some 25 percent.

TABLE 5.—*Summary of estimates of the South Bay lake trout population*

[The figures for the angling catch are the total catch reported; the marks of the current year are estimates based on examination of approximately 50 percent of the catch. Limits of error have not been computed but overall figures for the number of captures and recaptures are included as a rough guide to the stability of the estimates]

Year	Length groups (inches)	Schnabel-type estimate based on netting				Petersen-type estimate based on angling			
		Period	Number of fish released	Number of fish recaptured	Estimate	Catch	Fish with marks of current year	Fish marked	Estimate
1948	Combined.....	May 11-June 14	1,823	112	19,500	1,047	85	1,838	23,000
1949	Under 17.....	May 11-June 14	184	8	2,120	285	11	215	5,670
	17.....	do.	413	32	2,800	209	26	428	3,440
	18.....	do.	756	85	3,700	342	66	778	4,030
	19.....	do.	763	116	2,900	338	69	788	3,860
	20.....	do.	468	73	1,730	223	43	485	2,520
	over 20.....	do.	247	39	900	259	69	266	1,000
	Total.....	do.	.....	...	14,150	.....	..	.....	20,520
1950	Combined.....	May 18-June 29	606	50	4,160	418	36	603	7,000
1951	Combined.....	May 10-June 27	84	6	588	39	..	.....	.....
1949	All 1948 marks.....	May 11-June 14	472	105	1,350	.....	..	.....	.....

Captures of lake trout both in nets and by angling dropped markedly in 1950. In consequence it was not possible to stratify the estimates by size and further, due to the small numbers involved, the estimates are of necessity without hope of precision. The estimate based on the net fishery was 4,160, that for the sport fishery based on the returns of 1950 tags together with returns of 1949 tags also released from the nets in 1950 was 7,000. If these estimates are reasonable approximations of the size of the population in 1950, considerably more natural mortality had occurred since the estimate of the year before than that during the previous two seasons.

To assess further this mortality two estimates can be made of the mortality of fish carrying 1949 tags. The first is based on the number of 1949 marks estimated to have been taken on the fish captured by angling in comparison to the number of 1950 tags taken in the same way. The ratio was 47 1949 marks to 25 1950 marks with 456 1950 marks extant August 1. These data give an estimate of 857 for the 1949 marks extant in 1950. The second estimate is based on the net fishery which took 126 lake trout with 1949 marks while also taking 545 fish not so marked and from which the recaptures gave a population estimate of 4,160. From these data, the ratio of 126:545 in the fish handled gives an estimate of 957 for the population of fish with 1949 marks. The mean of these two estimates is approximately 900.

The number of lake trout bearing 1949 tags estimated to be extant in 1949 after those taken by angling were subtracted was 2,700. The natural mortality from release in 1949 up to the angling season of 1950 was of the order of 1,800 or 70 percent—a sharp increase over the mortality estimate for the previous year.

A very rough estimate of the number of 1948 marks extant in 1950 can also be made. Fifty-two 1948 marks were recognized in the net fishery during the period for which the population estimate was made and during which a total of 606 fish were taken for marking from a population estimated to consist of 4,160 trout. The estimate on this basis for 1948 marks extant is 356. In the sport fishery it is estimated that 24 1948 marks were taken that were not seen in the nets. This value, compared to the 36 fish recognized among the 606 released from the 1950 netting, yields an estimate of 404 for fish bearing 1948 marks not seen in the 1950 netting. The estimate for the total population of fish with 1948 marks is 456 since the 52 marked individuals seen in the netting must be added. A survival of 400 of the 1,350 estimated as extant the previous season, allowing for a fishing mortality of 10 percent, gives a value for the natural mortality of some 60 percent. This value is in good agreement with the estimate based on the 1949 marks.

Since the two estimates of the mortality of 1949 tags agree reasonably well, these data have been used to derive a rough estimate of the spawning in 1950. A sample of 143 lake trout was taken on the spawning beds in the autumn of that year. Most of these fish were ripe so that the sex was deter-

mined by squeezing them. There were 129 males, 7 females, and 8 sex undetermined in this sample. Twenty-five of the male fish in this sample bore 1949 tags. Assuming that the sex ratio for all fish bearing 1949 marks was 50–50 then the number of males bearing 1949 marks still extant in 1950 would be estimated at 450, half the estimate of 900 for all 1949 marks given above. If a further assumption is made, namely that all males bearing 1949 tags were likely to take part in the 1950 spawning run, then a Petersen-type estimate can be made of the number of spawning males. This estimate is approximately 2,400. The assumption that the 1949 marks were borne in a reasonably random fashion by the spawning population would appear to be approximately correct since they were on fish of a larger average size than were those bearing 1950 marks. The estimate for the spawning females would be 130 or 290 depending on whether the number of positively identified females is taken as indicative of the sex ratio or whether all fish not positively identified as males were females. The latter is perhaps the more likely, since among the mature lake trout examined in the creel census, the sex ratio was 92 males to 24 females. Since the females spawning in 1950 would shed on the order of 4,000 eggs each some 50,000 to 120,000 eggs were probably spawned in South Bay in the fall of 1950. This, as mentioned above, is believed to have been the largest spawning since 1947.

The number of lake trout taken in 1951 was very small; 110 were released and 19 killed in the net fishery and only 39 were recorded in the creel census. There were 6 recaptures in the spring net fishery during the period when 84 fish were released, and a Schnabel type estimate of 558 trout was made on the data of this very meagre fishery. No Petersen estimate could be made for the angling fishery despite the fact that 7 of the 22 examined bore tags. None of the tags found in the sample had been seen in the 1951 net fishery, so that there is no possibility of estimating the number of marks extant in the season of capture.

The pound- and trap-net fishery in 1952 yielded only about 40 lake trout, chiefly the last survivors of the 1944 year class and none was taken by angling. It appears therefore that the population of lake trout observed first in 1947 was virtually extinct by 1952.

The Sea Lamprey as a Factor in the Decline of the Lake Trout Stock

There appears to be little doubt that the major cause of the natural mortality suffered by the 1944 year class of lake trout after it entered the fishery was attack by the sea lamprey. No evidence of any other pathological condition was encountered during the large-scale examination of specimens taken during the passage of this year-class through the fishery. The reduction of the population was not catastrophic as might be expected if it had been caused by unusual hydrological conditions. On the other hand, there is a direct correlation between the incidence of lamprey marks given in Table 6 and the rate of reduction of the lake trout population.

The general increase in incidence of sea lamprey marks may be to some

extent due to the increase in the average size of the individuals making up the population which would make them more vulnerable to lamprey attack as was suggested by Van Oosten (1949). However, there is a marked increase in lamprey marks over all sizes which suggests an increase in the lamprey population in 1949 and 1950 as well.

Of the estimated 21,000 lake trout of fishable size present in South Bay in 1948 the anglers harvested no more than 3,500; the remainder fell prey to natural mortality. From this can be plainly seen, as Hile (1949) and

TABLE 6.—*Percentage of lake trout examined in South Bay bearing lamprey marks*
[The data for 1947 are from net samples. Those for all subsequent years are from creel-census samples. A blank indicates a negative finding on a sample of less than 10 fish; a number in parentheses indicates a positive finding. The population estimate is for the year indicated, The natural mortality estimate is the mortality which occurred since the year previous]

Year	Percentage of scarred lake trout by length (inches)							Population estimate	Estimate of natural mortality (percentage)
	under 19	19	20	21	22	23	over 23		
1947.....	0.9	3.2	0	0	0	0	52	high	..
1948.....	0	0	0	3.7	....	....	(33)	21,000	low
1949.....	1.0	2.4	5.8	4.7	14	7.7	....	18,000	25
1950.....	14	16	19	24	22	20	30	5,000	70
1951.....	....	....	....	....	(50)	(30)	30	600	high

Hile, Eschmeyer, and Lunger (1951) pointed out for the net fisheries of lakes Huron and Michigan, that fishing mortality cannot be considered the cause of the decline of lake trout populations where the lamprey is resident in the Great Lakes.

It is doubtful, although very little trust can be placed in the estimate for spawning escapement in 1950 given above, whether enough trout escaped mortality to provide spawn sufficient to reproduce another year class of a magnitude similar to that of 1944. A survival of some 25 percent to age IV would probably be required, which would surely be a phenomenal event.

The best prospects for a future lake trout fishery in South Bay until the lamprey can be curbed appears to be to plant yearling lake trout and to exploit these plantings as soon as the fish reach a length of 15 inches or so. Two experimental plants of lake trout yearlings with the adipose clipped have been made in 1949 and 1951, and a third planting is planned for 1952. Samples taken in 1952 yielded 63 lake trout of the 1949 plantings as opposed to 23 native fish of the same age, so that survival has been appreciable. In order to achieve practical success in this program even with good survival it would appear necessary to improve the technique used for taking lake trout by trolling in South Bay. There, as is common elsewhere in Ontario, trolling is ordinarily done with a metal line. The difficulty seems to be that South Bay, because of the magnitude of the sweep of its open water, has a thermocline which lies at a considerable depth while still having an epilimnial temperature above the preferendum for the lake trout. For these reasons summer fishing for best results should

probably be carried on at depths down to at least 15 fathoms. The amount of wire required to reach such a depth is probably well beyond the capacity of the ordinary trolling reel.

Literature Cited

DeLury, D. B.
1951. On the planning of experiments for the estimation of fish populations. J. Fish. Res. Bd. Canada, Vol. 8, pp. 281–307.

Fry, F. E. J., and W. A. Kennedy
1937. Report on the 1936 lake trout investigations, Lake Opeongo, Ontario. Univ. Toronto Stud. Biol. Ser. No. 42, Pub. Ont. Fish. Res. Lab. No. 54, 20 pp.

Hile, Ralph
1949. Trends in the lake trout fishery of Lake Huron through 1946. Trans. Am. Fish. Soc. Vol. 76 (1946), pp. 121–147.

Hile, Ralph, Paul H. Eschmeyer, and George F. Lunger
1951. Decline of the lake trout fishery in Lake Michigan. Fish. Bull., U.S. Fish and Wildlife Serv. Vol. 62, pp. 77–95.

Van Oosten, John
1949. Progress report on the sea lamprey study. The Fisherman, Vol. 17, No. 3, pp. 6, 9.

THE FISH POPULATION OF THE HEADWATERS OF A SPOTTED BASS STREAM IN SOUTHERN ILLINOIS [1]

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Abstract

There are a few relatively cool, clear-water, gravel-bottom streams in the southern tip of Illinois. These streams are of particular interest since they support populations of spotted bass and other game fishes. The present work considers the fish population of the headwaters of one of these stream systems, the Clear Creek drainage. This system includes about 15 miles of stream, made up of Clear Creek proper and its major tributary, Hutchins' Creek. With the exception of periods of excessive rainfall, the headwaters of the streams are in the form of pools 100 to 200 feet long separated by riffles and shallows 50 to 1,000 feet in length and ranging in width from 6 to 20 feet. Pool depths range up to 5 feet.

The pools were sampled by means of an electrofishing device at selected sampling stations located at intervals of about 1 mile or less. A sample consisted of the majority of the fish from a large pool along with those of the adjoining riffles.

Analysis of the populations included consideration of species composition, size composition, and determination of rate of growth and coefficient of condition where possible. Twenty-three species of fish were taken from the headwaters of the two streams. The principal species included: longear sunfish, *Lepomis megalotis* (Rafinesque); green sunfish, *Lepomis cyanellus* (Rafinesque); spotted bass, *Micropterus punctulatus* (Rafinesque); stoneroller, *Campostoma anomalum* (Rafinesque); bluntnose minnow, *Hyborhynchus notatus* (Rafinesque); creek chub, *Semotilus atromaculatus* (Mitchill); golden redhorse, *Moxostoma erythrurum* (Rafinesque); white sucker, *Catostomus commersoni* (Lacépède); rainbow darter, *Poecilichthys caeruleus* (Storer); and madtom, *Schilbeodes insignis* (Richardson).

The stoneroller was by far the most abundant fish. The longear and green sunfish were common enough to furnish some fishing. The spotted bass was very scarce although it is known to be present in larger numbers in these waters in the spring. The population of green and longear sunfish included a surprisingly large number of larger fish. It was concluded that heavy predation on younger fishes probably accounted for this unusual size distribution.

Introduction

In the southern tip of Illinois there is an outcrop of Devonian limestone of approximately 300 square miles. Much of this region is drained by Clear

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Creek and its major tributary, Hutchins' Creek. That portion of the Clear Creek system which might be considered of interest for the production of game fishes has a length of about 15 miles. These streams are readily accessible and are most picturesque. The water is relatively clear, cool, and well aerated, and the water-level fluctuation is not more than 2 feet on Hutchins' Creek and not more than 3 feet on Clear Creek proper.

The streams of the Clear Creek system, except at extreme high-water stage, are in the form of pools, 100 to 200 feet long separated by riffles and shallows 500 to 1,000 feet in length. Pool widths vary from 6 feet to 20 feet. Pool depths range up to 5 feet.

These streams are partly spring-fed and continue to run throughout the summer months. The water temperature is usually lower than the air temperature by about 10°F.

The middle and upper portions of the Clear Creek system lie in narrow valleys. In many places, the valley is not more than a mile wide. The ridges delimiting the valley rise steeply on each side and are forested with a growth of beech and oak. Much of the valley is under cultivation.

Gravel is the predominate bottom type in all of the streams. The bottom of Hutchins' Creek is entirely gravel of size ranging from ½-inch up to 2 or more inches. Clear Creek proper has a gravel bottom with occasional stretches of sand. Downstream from the point where Hutchins' joins Clear Creek proper, the gravel is overlaid with silt and the stream gradually becomes sluggish, without riffles, and with deeply cut banks.

Method of Study

The fish populations were sampled by means of an electric shocker in order to gain data as to species composition, size composition, rate of growth, and other information that might reveal the status of the fish population. The shocker utilized was a 230-volt, AC, 1500-watt, portable generator. The generator was equipped with a 100-foot 12/2 cable attached to a pair of electrodes. The electrodes were constructed of wood, 1 inch by 2 inches by 8 feet, with the lower 30 inches wrapped with a sheet of aluminum. The apparatus was operated by three persons, two of whom, while wading the stream, manipulated the electrodes and netted fish. The third person operated the generator, collected the fish netted by the electrode operators, and netted fish himself as time permitted.

The streams were sampled at selected stations located at intervals of ¼-mile to more than 1 mile. On Hutchins' Creek, starting in the lower end, the stations were identified by the letters A to K. On Clear Creek, commencing in the headwaters, the stations were identified by numbers 1 to 7. A sample at a particular station was made up of the majority of the fish population of a prominent pool in that segment of the stream.

The present paper is based primarily on samples taken in August 1951.

The fish sample was placed in 10-percent formalin in the field and returned to the laboratory. Study of the samples was started in September

and completed in February. Thus the maximum time the specimens remained in formalin was 6 months. It is recognized that some error in weight and length is introduced by holding fish in a formalin solution. Carlander's (1950) résumé on the change in length due to formalin preservation lists losses of from 1 to 5 percent. The only pertinent data for weight appear to be those reported by Sigler (1949), who reported a weight gain of approximately 5 percent.

Detailed laboratory examinations varied for the different species. For the green sunfish, longear sunfish, spotted bass, bluegill, creek chubsucker, and golden redhorse, standard and total lengths were taken. The specimens were weighed to the nearest gram on a platform, spring balance. Ages were determined by the scale method. The fish were superficially examined for parasites externally and internally. Treatment of the stoneroller was similar except that for this species ages were estimated by length-frequency distribution and weights were not determined.

Where the number of specimens was adequate and when it was felt that the weight of the species was of importance, length-weight relationship and values of the coefficient of condition were determined in accordance with procedures and definitions used by Hile (1936). In addition, agreement between observed weights and those calculated by use of length-weight equations was checked by determining a correlation coefficient from the formula:

$$\text{Correlation coefficient} = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{N\Sigma X^2 - (\Sigma X)^2}\ \sqrt{N\Sigma Y^2 - (\Sigma Y)^2}},$$

where X = log standard length,
Y = log weight,
and N = number of specimens.

Because the number of specimens was limited, body-scale relationships were not determined. Calculation of growth prior to capture was made on the assumption of a constant ratio between scale radius and body length.

The limited number of specimens, or with some fish the impracticability of using the scale method, prevented detailed analysis of growth for 13 of the 23 species taken.

Since for most species there exists only a limited amount of comparative data, no attempt is made in the present work to compare growth rates and coefficients of condition of the various species with values reported from other studies. If such a comparison is desired, it can easily be made by use of *Handbook of Freshwater Fishery Biology* (Carlander, 1950).

Twenty-three species of fishes were taken from the two streams. The numerically important species were about equally well represented in both streams. In the discussion of the following sections, the fishes are divided into game, bait, and miscellaneous forms. Within each group the species are listed according to their abundance.

Game Species

Five species of game fishes were represented in the waters under consideration.

Longear sunfish.—The hydrography of Clear and Hutchins' Creeks makes these streams particularly attractive to the fly fisherman. In such streams the longear sunfish has some value for angling. It never reaches a length of more than 6 or 7 inches, but it is a beautiful fish and readily takes fly-rod lures or angleworms. It is found in most of the streams, rivers, and larger lakes of southern Illinois. In the rivers and larger bodies of water, the longear is overshadowed by many larger and more sought-after fishes, but in the clear-water, rocky streams of the Clear Creek type, its occurrence is well recognized even by the more casual fisherman.

The longear sunfish constituted 5 percent of the total number of fish taken from the drainage system. The oldest specimen collected in the course of the study was 5 years of age (Table 1). Age-groups I, II, III,

Table 1.—*Growth rates of longear sunfish taken from Hutchins' and Clear Creek in August 1951*

Age group	Number of fish	Average standard length at capture (millimeters)	Average weight at capture (grams)	Calculated standard length (millimeters) at end of year				
				1	2	3	4	5
I	36	60	7	29	...	...	...	...
II	42	85	20	37	64	...	...	...
III	30	106	46	32	65	88	...	...
IV	16	120	62	31	60	85	106	...
V	9	131	84	31	61	88	107	121
Weighted mean standard length (millimeters)				33	63	87	107	121
Total length (inches)[1]				1.6	3.1	4.2	5.2	5.8
Annual length increment (millimeters)				33	31	24	21	14
Annual weight increment (grams)				1	8	15	23	22

[1] Length conversions based on 161 specimens ranging from 46 to 137 millimeters in standard length: total length (inches) = 0.048 standard length (millimeters); standard length (millimeters) = 20.92 total length (inches)

and IV were well represented but 0-group fish were lacking. Their absences may have indicated a spawning failure. The longear sunfish attained a minimum catchable size of about 5 inches, total length, by the end of the fourth year of life. Their K value was 3.56. The length-weight equation for the Clear Creek system is: $\log W = -4.77 + 3.16 \log L$ with a correlation coefficient of 0.963. This equation, as well as the K value, is based on 164 specimens with a range in standard length of 47 to 137 millimeters.

Green sunfish.—The green sunfish made up 3 percent of the collections. This species when of a desirable size is of value as a game fish. It will take fly-rod lures as well as live bait. It is recognized that in the more northern areas the green sunfish is considered a nuisance, but in the southern part of Illinois it is not uncommon to find both stream and lake populations which contain a fairly high percentage of catchable-size fish.

The oldest green sunfish taken was 6 years old (Table 2) and with the exception of 0-group fish the lesser ages were well represented. This condition may indicate spawning failure. The green sunfish reached a catchable size of approximately 5 inches, total length, by the end of its third year. Its mean coefficient of condition was 3.19. The length-weight relationship for the species is expressed by the formula: $\log W = -4.89 + 3.19 \log L$ with a correlation coefficient of 0.980. This equation and the coefficient of condition value are based on 83 specimens ranging in standard length from 55 to 199 millimeters.

Spotted bass.—The spotted bass was poorly represented in the collec-

TABLE 2.—*Growth rates of green sunfish taken from Hutchins' and Clear Creeks in August 1951*

Age group	Number of fish	Average standard length at capture (millimeters)	Average weight at capture (grams)	Calculated standard length (millimeters) at end of year					
				1	2	3	4	5	6
I	36	68	10	37	...	...	...	...	...
II	17	94	29	41	73	...	...	...	...
III	12	125	67	39	75	108	...	...	...
IV	7	147	110	43	77	107	132	...	...
V	4	157	134	43	78	109	132	147	...
VI	2	190	222	40	72	106	138	167	182
Weighted mean standard length (millimeters)				39	76	109	135	154	182
Total length (inches)[1]				1.8	3.5	5.1	6.3	7.3	8.6
Annual length increment (millimeters)				39	35	32	26	20	15
Annual weight increment (grams)				1	10	26	34	44	42

[1] Length conversions based on 81 specimens ranging from 51 to 199 millimeters in standard length: total length (inches) = 0.047 standard length (millimeters); standard length (millimeters) = 21.23 total length (inches)

tions under consideration since in the summer months this species moves downstream to the larger pools of the lower waters. Spring sampling and field observations demonstrated these movements. In the present sample, the spotted bass constituted less than 1 percent of the fish collected.

The collections included 18 spotted bass. Ten of these were 0-group fish with a mean total length of 2.0 inches. The other 8 bass were all I-group fish with a mean total length of 6.8 inches and a calculated total length at the first annulus of 3.1 inches. The mean coefficient of condition was 2.46.

Yellow bullhead, Ameiurus natalis (*Le Sueur*).—Several catchable-size yellow bullheads were taken in the stream system. This species represented less than 1 percent of the total collection. However, this species is not of much value for angling in a stream such as Clear Creek. Worm fishing is somewhat unsatisfactory in pools containing large numbers of minnows and other small fishes. Furthermore, the bait fisherman is not interested in "working" a large area of stream in order to produce a catch of fish whereas the fly fisherman would not find such a practice objectionable.

Black bullhead, Ameiurus melas (*Rafinesque*).—Only one specimen of the black bullhead was taken. There is no indication that this species is of importance in any of the streams under consideration.

Bait Species

At the time of this survey, the streams of the Clear Creek system were more heavily utilized as a source of bait than they were for sport fishing. However, as mentioned above, spotted bass are abundant in these waters during the spring and the streams can be managed and utilized for sport fishing. Six bait species were taken.

Stoneroller.—The stoneroller was by far the most abundant fish found in the headwaters of the Clear Creek drainage. It comprised 65 percent of the total collection. This species was often seen in schools composed of hundreds of individuals, and it made up the greater part of each sample.

The stoneroller is a typical stream fish and hence not reared commercially as a bait species, but collected from its natural environment for this purpose. It is considered an excellent bait for the black basses. Both commercial and private seining of this species are carried on in the headwaters of the Clear Creek system.

The scale method of age determination did not prove satisfactory for the stonerollers and since there was a fairly large sample available, age was deduced from length-frequency distribution (Fig. 1). All data relevant to the collections from Clear Creek and its principal tributary, Hutchins' Creek, were originally analyzed separately, but since for the majority of the species there was no significant difference between the various analyses, the data were combined and treated as being from one population. The length distributions of the stonerollers were an exception in that the distribution from Clear Creek showed a mode at 46 millimeters which was not evident in the combined data; hence, these statistics are given separately.

The age interpretation which appears most logical to the authors is that in the Clear Creek distribution there is a 0-group mode at 46, a I-group mode at 62, and a II-group mode at 76 millimeters of standard length. For the Hutchins' Creek distribution, the I-group mode is at 60 and the II-group mode is at 80 millimeters. There appears to be no mode for age-group 0 in the Hutchins' Creek distribution. Possibly a mode would have occurred at 45 had it not been obscured by the large one-year group.

Bluntnose minnow.—The bluntnose was second in importance among the bait species, representing 10 percent of the collection from the Clear Creek drainage. This species is considered excellent crappie bait and is taken commercially and privately throughout the drainage area.

Creek chub.—The creek chub represented 4 percent of the total collection. Unfortunately, scale samples from Clear Creek proper were lost so no growth analysis was made on this part of the system.

In the sample of the Clear Creek tributaries, age-groups 0, I, II, and III were represented. This species had reached a desirable bait size by the

end of its first summer and was still usable for bait at 3 years of age (Table 3). Its mean coefficient of condition was 1.75 and its length-weight relationship was: log $W = -4.49 + 2.86 \log L$ with a correlation coefficient of 0.995. This analysis was based on 43 specimens in the standard length range 45 to 193 millimeters.

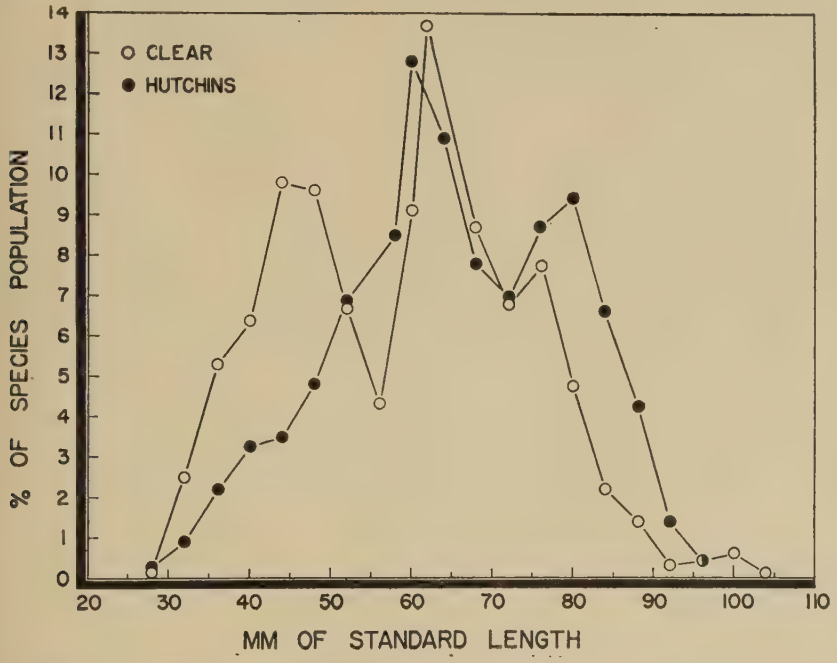

FIGURE 1—Length-frequency distribution of the populations of stonerollers, based on collections of 716 specimens from Clear Creek and 1,559 from Hutchins' Creek, August 1951.

Creek chubsucker, Erimyzon oblongus (*Mitchill*).—Of the 60 specimens of the creek chubsucker obtained, 38 were I-group fish and 22 were in age-group II. They attained a total length of 2.0 inches at the end of their first year and 4.2 at the end of their second (Table 4). The mean coefficient of condition was 2.12. Their length-weight relationship is expressed by the equation: log $W = -4.83 + 3.08 \log L$ with a correlation coefficient of 0.984. The value of the coefficient of condition and the length-weight equation are based on 56 specimens in the standard length range 65 to 168 millimeters.

Common shiner, Notropis cornutus (*Mitchill*).—The common shiner ranges in length up to sizes suitable for bass bait. It is taken commercially and privately, but was not found to be abundant. It constituted slightly more than 1 percent of the total collection.

Redfin shiner, Notropis umbratilis (*Girard*).—The redfin shiner was

much sought after as crappie bait but was not particularly abundant. It made up less than 1 percent of the fish collected.

TABLE 3.—*Growth rates of creek chub taken from Hutchins' Creek in August 1951*

Age group	Number of fish	Average standard length at capture (millimeters)	Average weight at capture (grams)	Calculated standard length (millimeters) at end of year		
				1	2	3
0	6	61	4	...	...	...
I	16	87	13	46	...	...
II	8	138	50	59	112	...
III	5	168	77	67	111	144
Weighted mean standard length (millimeters)				53	112	144
Total length (inches)[1]				2.5	5.2	6.7
Annual length increment (millimeters)				53	50	33
Annual weight increment (grams)				3	16	23

[1] Length conversions based on 43 specimens ranging from 45 to 196 millimeters in standard length: total length (inches) = 0.047 standard length (millimeters); standard length (millimeters) = 2.14 total length (inches)

TABLE 4.—*Growth rate of creek chubsucker taken from Hutchins' and Clear Creeks in Augus 1951*

Age group	Number of fish	Average standard length at capture (millimeters)	Average weight at capture (grams)	Calculated standard length (millimeters) at end of year	
				1	2
I	29	85	14	39	..
II	22	122	40	43	86
Weighted mean standard length (millimeters)				40	86
Total length (inches)[1]				1.9	4.1
Annual length increment (millimeters)				40	40
Annual weight increment (grams)				1	11

[1] Length conversions based on 54 specimens ranging from 47 to 168 millimeters in standard length: total length (inches) = 0.047 standard length (millimeters); standard length (millimeters) = 2.12 total length (inches)

MISCELLANEOUS SPECIES

Eleven species were placed in this category.

Golden redhorse.—The golden redhorse is of no value as a commercial or game species. It is questionable whether it is of any importance as a forage species in streams such as Clear Creek, and it is common enough to be of importance as a competitor of the desirable species.

The oldest specimens taken were 5 years of age (Table 5). The majority of specimens were 1 and 2 years old. The 2 V-group specimens which were taken had reached a length of approximately 12 inches by the end of their fifth year. The mean coefficient of condition was 2.01. There was a slight indication of an upward trend of K with an increase in body length. The length-weight relationship for this species is expressed by the equation:

$\log W = -4.85 + 3.07 \log L$ with a correlation coefficient of 0.985. The K value and length-weight equation are based on 72 specimens in the standard length range 74 to 272 millimeters.

TABLE 5.—*Growth rates of golden redhorse taken from Hutchins' and Clear Creeks in August 1951*

Age group	Number of fish	Average standard length at capture (millimeters)	Average weight at capture (grams)	Calculated standard length (millimeters) at end of year				
				1	2	3	4	5
I	29	94	17	42	...	...	...	...
II	26	148	74	46	98	...	...	...
III	5	212	200	41	100	165	...	...
V	2	284	751	38	94	164	214	257
Weighted mean standard length (millimeters)				44	98	170	215	258
Total length (inches)[1]				2.2	4.7	8.2	10.3	12.4
Annual length increment (millimeters)				44	53	70	49	43
Annual weight increment (grams)				1.5	16	81	129	162

[1] Length conversions based on 73 specimens ranging from 74 to 295 millimeters in standard length: total length (inches) = 0.048 standard length (millimeters); standard length (millimeters) = 20.76 total length (inches)

TABLE 6.—*Growth rates of white sucker taken from Hutchins' and Clear Creeks in August 1951*

Age group	Number of fish	Average standard length at capture (millimeters)	Average weight at capture (grams)	Calculated standard length (millimeters) at end of year				
				1	2	3	4	5
0	8	53	3	...	...	...	...	...
I	20	117	313	58	...	...	...	...
II	5	145	54	35	94	...	...	...
III	4	182	118	34	84	130	...	...
IV	3	226	221	26	77	144	189	...
V	2	256	299	34	64	117	192	237
Weighted mean standard length (millimeters)				44	87	136	112	141
Total length (inches)[1]				0.8	2.2	3.6	5.2	6.6
Annual length increment (millimeters)				44	52	53	33	27
Annual weight increment (grams)				2.4	2.4	24	50	90

[1] Length conversions based on 62 specimens ranging from 42 to 263 millimeters in standard length: total length (inches) = 0.047 standard length (millimeters); standard length (millimeters) = 21.33 total length (inches)

White sucker.—The white sucker in the Clear Creek drainage is of no significance as a game or commercial species. It may destroy spawn of other fishes and its spawning in such streams as Clear Creek may be important in maintaining the sucker population of the Mississippi River. It made up 2 percent of the stream collections. The oldest specimen taken was 5 years old and measured 11 inches total length (Table 6). The mean coefficient of condition for the specimens was 1.72. The length-weight relationship for the Clear Creek drainage fish is expressed by the equation: $\log W = -4.94 + 3.08 \log L$ with a correlation coefficient of 0.987. The

length-weight equation and coefficient of condition value are based on 62 specimens in the standard length range 42 to 263 millimeters.

Rainbow darter.—The rainbow darter comprised 2 percent of the total collection. This species appeared to have a definite preference for the riffles rather than the deeper quieter waters.

Madtom.—The madtom made up 2 percent of the collections. This species also appeared to prefer the riffles.

The occurrence of seven other species should be recorded. They were: logperch, *Percina caprodes* (Rafinesque); freshwater sculpin, *Cottus bairdi* Girard; pirate-perch, *Aphredoderus sayanus* (Gilliams); johnny darter, *Boleosoma nigrum* (Rafinesque); fantail darter, *Poecilichthys flabellaris* (Rafinesque); grass pickerel, *Esox vermiculatus* Le Sueur; and carp, *Cyprinus carpio* Linnaeus.

Fishery Values in Southern Illinois Streams

In southern Illinois, the impervious soil and rolling topography make the construction of artificial impoundments readily feasible and many have been constructed. There is a danger that stream management may be overlooked. It is suggested that clear-water, accessible, picturesque streams, offering recreational fishing are a valuable resource. There are probably not more than 200 miles of clear-water streams in the southern quarter of Illinois. Every effort should be made to survey these streams as soon as possible and to take steps to prevent damage by deforestation, cultivation, and related activities. The present survey indicates that some of these streams could produce sport fishing and their value in the production of bait species is already known. They appear to afford an ideal environment for the stoneroller and the bluntnose minnow, which are two much sought-after bait species. There is no time of the year at which bait species cannot be obtained from these streams.

Hutchins' and Clear Creeks have not been greatly affected by man and hence the species composition, as determined by the present survey, is probably the normal population of this type of stream. Of the fish involved the more southerly species are in the majority. The stream type would perhaps be classed with those of the general Ozark area.

Literature Cited

Carlander, Kenneth D.
1950. Handbook of freshwater fishery biology. Wm. C. Brown Company, Dubuque, Iowa, v + 281 pp.

Hile, Ralph
1936. Age and growth of the cisco, *Leucichthys artedi* (Le Sueur), in the lakes of the northeastern highlands, Wisconsin. Bull. U. S. Bur. Fish, Vol. 43, pp. 211–317.

Sigler, William F.
1949. Life history of the white bass, *Lepibema chrysops* (Rafinesque), of Spirit Lake, Iowa. Iowa State Coll. Agr. Exp. Sta., Res. Bull. No. 366, pp. 203–244.

THE BOTTOM FAUNA OF LOUISA AND REDROCK LAKES, ALGONQUIN PARK, ONTARIO

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ABSTRACT

Bottom-fauna surveys of Louisa and Redrock Lakes were carried out to supplement previous investigations of the fisheries. The average weight per animal and the depth distribution of the various organisms is discussed. Migrations of *Chaoborus* larvae are demonstrated. The average quantity of bottom fauna in Louisa Lake was 1.64 pounds per acre, dry weight, in August and 2.15 in October. Redrock Lake contained 2.73 pounds per acre in September and an estimated 3.28 pounds per acre in October. There was little difference in the amounts of bottom organisms at comparable depths between the two lakes at the same time of year. The greater relative area of the highly productive 0- to 15-foot depth zone in Redrock Lake accounted for its larger average bottom fauna. The feeding of the lake trout upon the bottom fauna was also in proportion to the relative areas of shallow bottom in each lake.

INTRODUCTION

Lakes Louisa and Redrock are located in the Precambrian Shield of Canada about 100 miles north of Lake Ontario. The author surveyed the bottom fauna of these lakes as part of a general fishery investigation by the Division of Research, Department of Lands and Forests, Province of Ontario. These lakes have been under creel census for 17 years (Fry, 1939, and Fry and Chapman, 1948). In addition, the lake trout of both lakes were studied by Martin (1952), and the eastern brook trout of Redrock Lake by Baldwin.[1]

DESCRIPTION OF THE LAKES

The lakes were fully described and compared by Martin (1952) and contour areas from his study are shown in Table 1. Lake Louisa contains 1,500 acres, has a maximum depth of 210 feet, a mean depth of 65 feet, and is situated among low hills of Precambrian rock. Redrock Lake contains 746 acres, has a maximum depth of 76 feet, a mean depth of 29 feet, and has sandy shores and extensive shallow areas.

[1] Baldwin, N. S., 1948. A study of the speckled trout, *Salvelinus fontinalis* (Mitchill), in a Precambrian lake. M.A. thesis, University of Toronto.

Methods

Bottom samples were taken singly at widely scattered points over the area of each lake. A 9-inch Ekman dredge was used on Louisa Lake and a 6-inch Ekman dredge on Redrock Lake. Louisa Lake was visited on August 4–6, 1947, (56 samples) and again on October 23–30, 1947, (65 samples). Redrock Lake was visited on September 10–11, 1947, (32 samples). The number of samples taken at each depth in these lakes is shown in Table 1. The samples were washed through a pair of 30- and 50-mesh screens. The washing was done on the lake and the organisms were preserved in 10-percent formalin for later identification and enumeration.

Table 1.—*The area in acres and percentage of the total area of the depth zones in Louisa and Redrock Lakes*
[Data from Martin, 1952. The number of bottom samples taken from each zone is also given]

Item	Depth zone (feet)							Total
	0-15	15-30	30-45	45-60	60-75	75-150	150-210	
Redrock Lake								
Area (acres)	325	65	150	115	91	...	...	746
Percentage of total area	44	9	20	15	12	...	...	100
Number of samples	9	7	5	5	6	...	...	32
Louisa Lake								
Area (acres)	235	295	212	118	105	363	172	1500
Percentage of total area	16	20	14	8	7	24	11	100
Number of samples (August)	12	12	8	4	4	16	0	56
Number of samples (October)	8	12	5	6	5	16	13	65

The Weight of the Organisms

The collection from Redrock Lake and the two from Louisa were sorted separately into taxonomic groups, dried for 48 hours at 56°C. and weighed on an analytic balance. The dry weight obtained amounted to approximately 10-percent of the wet weight. Average dry weights per animal of the organisms are shown in Table 2. The dried animals ranged in weight from 0.13 to 24.10 milligrams. In order of decreasing dry weight the groups ranked as follows: Oligochaeta, 24.10; Ephemeroptera 5.79; *Sialis,* 2.27; Amnicolidae (without shell), 0.86; Chironomidae, 0.71; Nematoda, 0.34; *Chaoborus,* 0.30; *Hyalella,* 0.14; and Sphaeriidae (without shell) 0.13. The weights from Table 2 were used to convert population estimates by numbers to weight-based estimates. The unit of weight used in this paper is the pound per acre (1 cubic centimeter volume per square foot was equivalent to 9.6 pounds per acre dry weight).

The Depth Distribution of the Organisms

The number and weight of bottom organisms at each depth are given in Table 3 for Redrock Lake and in Tables 4 and 5 for Louisa Lake. The

results of the dredgings were averaged by 15-foot depth zones to a depth of 75 feet, and in 75-foot zones from there to the greatest depth.

Groups of organisms that occurred in both deep and shallow water were, in order of abundance: Chironomidae and *Chaoborus*, Sphaeriidae, Oligochaeta, and Nematoda. They were the only groups collected below the 45-foot contour, and were also (with the exception of Nematoda) well represented in the shallows.

TABLE 2.—*The average dry weight (milligrams) per animal of the organisms in the three collections*

Organism	Louisa Lake		Redrock Lake	Organism	Louisa Lake		Redrock Lake
	August	October	September		August	October	September
Nematoda	....	0.34	....	*Chaoborus* sp.	0.30	0.20	0.19
Oligochaeta	24.10	0.52	2.69	Chironomidae	0.59	0.71	0.41
Hyalella sp.	0.14	....	....	Amnicolidae	[1]0.86	....	....
Sialis sp.	2.27	1.55	1.03	Sphaeriidae	[1]0.13	....	....
Ephemeroptera	3.27	5.79	1.16	Miscellaneous	....	....	1.55

[1] Weight of shell deducted

A variety of forms inhabited the shallow water. The most important of these were Ephemeroptera, *Sialis*, and the dipterous larvae previously mentioned. The miscellaneous organisms and their numbers per square foot in Redrock Lake were: Turbellaria, 0.4; Odonata, 0.9; Trichoptera, 1.3; and *Planorbis*, 0.4.

The distribution of Ephemeroptera and *Sialis* differed between the two lakes. These groups lived at depths down to 45 feet in Louisa Lake, but were found only at 0-to 13 feet in Redrock Lake.

The distribution of *Chaoborus* (*Corethra*), a semi-planktonic larva, varies throughout the year. Borutsky (1939) demonstrated horizontal and vertical migrations of these larvae in White Lake, Russia. Similar migrations were observed by the author for three other Algonquin Park lakes (unpublished manuscript). The larvae migrated towards shore in the spring about the middle of April prior to pupation and emergence as adults. A new population of larvae developed during the summer, and, near the beginning of September, began a migration away from shore which lasted until midwinter. At this time in a *Corethra* lake the larvae may reach concentrations of up to 6,500 per square foot at the greatest depth. It is well known that these larvae also undertake nocturnal migrations, rising up into the upper water layers between sunset and sunrise. The very young larvae may be planktonic both night and day.

The August sampling of Louisa Lake (Table 4) found the *Chaoborus* population at low ebb, with its greatest abundance at 5.0 per square foot in the 0-to 15-foot zone. Fewer than 0.5 per square foot were taken below the 45-foot depth. Undoubtedly a great many young larvae were free-swimming at this time, for in October (Table 5) the larvae were relatively

abundant on the lake bottom. The larvae occurred at all depths, and there was a peak of abundance at 0-30 feet of 40.9 per square foot and a second peak of 25.6 per square foot at 60 to 75 feet.

This bimodal depth distribution in October indicates separate populations in Louisa Lake. One population occurred at the isolated ends of the long bays into which the lake is dissected, and the other in the open lake.

TABLE 3.—*Numbers and dry weight of the bottom organisms at each depth of Redrock Lake, September 10-11, 1947*

[Weights in pounds per acre are in parentheses directly below corresponding numbers of individuals per square foot]

Organism	Depth zone (feet)					Weighted total[1]	Percentage of total for entire lake
	0-15	15-30	30-45	45-60	60-75	0-75 feet	
Oligochaeta	4.3	.....	.....	.....	1.9	2.1	3.3
	(1.11)	.....	.....	.....	(0.49)	(0.54)	(19.8)
Hyalella sp.	18.7	.....	.....	.....	.....	8.11	12.8
	(0.25)	.....	.....	.....	.....	(0.11)	(4.0)
Sialis sp.	3.6	.....	.....	.....	.....	1.6	2.5
	(0.35)	.....	.....	.....	.....	(0.15)	(5.5)
Ephemeroptera	5.3	.....	.....	.....	.....	2.3	3.6
	(0.59)	.....	.....	.....	.....	(0.26)	(9.5)
Chaoborus sp.	0.9	88.5	43.2	32.0	43.3	27.2	42.8
	(0.02)	(1.60)	(0.79)	(0.58)	(0.79)	(0.50)	(18.3)
Chironomidae	13.3	8.0	35.6	13.6	12.7	17.3	27.2
	(0.52)	(0.31)	(1.40)	(0.53)	(0.50)	(0.68)	(24.9)
Amnicolidae	8.0	.....	.....	.....	.....	3.5	5.5
	(0.66)	.....	.....	.....	.....	(0.29)	(10.6)
Miscellaneous	3.0	.....	.....	.....	.....	1.4	2.2
	(0.46)	.....	.....	.....	.....	(0.20)	(7.3)
Total	57.1	96.5	78.8	45.6	57.9	63.5	.....
	(3.96)	(1.91)	(2.19)	(1.11)	(1.78)	(2.73)	.....

[1] Total obtained by multiplying the quantity of fauna in each depth zone by the corresponding zonal area from Table 1, summing the result and dividing that sum by the total area of the lake

Presumably during the offshore migration the latter group of larvae moved into the 210-foot depth of the open lake, while the former remained in the isolated shallow areas at the ends of the long bays.

The *Chaoborus* in Redrock Lake had a unimodal depth distribution with a maximum of 88.5 per square foot in the 15- to 30-foot zone in September. Above this depth very few larvae were found, and at greater depths they amounted to 32.0 to 43.3 per square foot. This distribution may be explained by assuming that the offshore migration had just begun in Redrock Lake by this time and many larvae had accumulated at 15-30 feet prior to their migration to greater depths.

TABLE 4.—*Numbers and dry weight of the bottom organisms at each depth of Louisa Lake, August 4-6, 1947*
[Weights in pounds per acre are in parentheses directly below corresponding numbers of individuals per square foot]

Organism	Depth zone (feet)							Weighted total[1]	Percentage of total for entire lake
	0-15	15-30	30-45	45-60	60-75	75-150	150-210	0-210 feet	
Oligochaeta	0.8	.....	.....	.....	.....	.....	.....	0.1	0.5
	(1.85)	.....	.....	.....	.....	.....	.....	(0.29)	(17.7)
Hyallela sp.	0.3	.....	.....	.....	.....	.....	.....	.....	.....
	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sialis sp.	0.3	0.4	0.2	.....	.....	.....	.....	0.2	1.1
	(0.06)	(0.09)	(0.04)	.....	.....	.....	.....	(0.03)	(1.8)
Ephemeroptera	4.1	4.3	0.4	.....	.....	.....	.....	1.5	8.2
	(1.28)	(1.35)	(0.13)	.....	.....	.....	.....	(0.48)	(29.3)
Chaoborus sp.	5.0	1.0	2.0	0.4	.....	0.1	.....	1.3	7.1
	(0.14)	(0.03)	(0.06)	(0.01)	.....	.....	.....	(0.04)	(2.4)
Chironomidae	2.2	3.3	12.4	26.7	25.8	19.7	19.7	13.7	74.5
	(0.12)	(0.19)	(0.70)	(1.51)	(1.46)	(1.13)	(1.12)	(0.78)	(47.6)
Sphaeriidae	0.8	2.2	2.2	.....	4.9	1.3	.....	1.6	8.7
	(0.01)	(0.03)	(0.03)	.....	(0.06)	(0.02)	.....	(0.02)	(1.2)
Total	13.5	11.2	17.2	27.1	30.7	21.1	19.7	18.4	.....
	(3.46)	(1.69)	(0.96)	(1.52)	(1.52)	(1.15)	(1.12)	(1.64)	.....

[1] See footnote to Table 3

TABLE 5.—*Numbers and dry weight of the bottom organisms at each depth of Louisa Lake, October 23-30, 1947*
[Weights in pounds per acre are shown in parentheses directly below corresponding numbers of individuals per square foot]

Organism	Depth zone (feet)							Weighted total[1]	Percentage of total for entire lake
	0-15	15-30	30-45	45-60	60-75	75-150	150-210	0-210 feet	
Nematoda	.....	.....	.....	.....	.....	0.1	1.4	0.2	0.6
	.....	.....	.....	.....	.....	.....	(0.05)	.....	(0.1)
Oligochaeta	.....	.....	.....	.....	0.3	0.1	0.3	0.1	0.3
	.....	.....	.....	.....	(0.02)	(0.01)	(0.01)	.....	(0.2)
Hyalella sp.	0.2	.....	.....	.....	.....	.....	.....	.....	.....
	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sialis sp.	0.2	0.1	0.7	.....	.....	.....	.....	0.1	0.3
	(0.03)	(0.02)	(0.10)	.....	.....	.....	.....	(0.02)	(0.9)
Ephemeroptera	5.6	2.7	1.1	.....	.....	.....	.....	1.6	4.5
	(3.10)	(1.50)	(0.61)	.....	.....	.....	.....	(0.87)	(40.5)
Chaoborus sp.	40.2	41.6	1.4	6.2	25.6	11.2	0.2	19.7	55.8
	(0.77)	(0.80)	(0.03)	(0.12)	(0.49)	(0.21)	.....	(0.37)	(17.2)
Chironomidae	11.6	2.4	15.6	11.2	18.5	15.8	18.6	12.6	35.7
	(0.79)	(0.16)	(1.06)	(0.76)	(1.26)	(1.08)	(1.27)	(0.86)	(40.0)
Amnicolidae	0.4	0.3	.....	.....	.....	.....	.....	0.1	0.3
	(0.03)	(0.02)	.....	.....	.....	.....	.....	(0.01)	(0.05)
Sphaeriidae	1.6	0.4	0.7	0.9	1.1	1.3	.....	0.9	2.5
	(0.02)	.....	(0.01)	(0.01)	(0.01)	(0.01)	.....	(0.01)	(0.5)
Total	59.8	47.5	19.5	18.3	45.5	28.5	20.5	35.3	.....
	(4.74)	(2.50)	(1.81)	(0.89)	(1.78)	(1.31)	(1.33)	(2.15)	.....

[1] See footnote to Table 3

Seasonal Changes in the Quantity of Bottom Fauna

Louisa Lake.—The *Chaoborus* migrations discussed in the preceding section concern a seasonal change in distribution together with a quantitative change between the two sampling periods. A comparison of the weighted totals (0-210 feet) in Tables 4 and 5 reveals further seasonal changes during this 12-week interval. Ephemeroptera increased in number from 1.5 to 1.6 per square foot and in weight from 0.48 to 0.87 pound per acre. This change indicates a growth in size with little change in number. The same is true for the Chironomidae which decreased in number from 13.7 to 12.6 per square foot, but increased in weight from 0.78 to 0.86 pound per acre. The *Chaoborus* discussed above increased from 1.3 to 19.7 larvae per square foot, and from 0.04 to 0.37 pound per acre—a considerable growth both in number and weight.

During this same time Oligochaeta decreased in quantity from 0.1 per square foot and 0.29 pound per acre to a trace. This change reflects biased sampling. The worms taken in August were found in a submerged meadow at the end of a long arm of the lake—a very restricted habitat which was not visited in October. Their enormous size in comparison with the other animals collected also biased the results. It would seem that productivity estimates which depend upon too few samples from the littoral zone are subject to important errors.

Redrock Lake.—Miller [2] took 60 samples from Redrock Lake with a 6-inch Ekman dredge during July 5–23, 1936, and found 1.5 pounds per acre of bottom fauna. The percentage composition by weight was as follows: Oligochaeta, 2.3; *Sialis,* 2.4; Ephemeroptera, 40.3; *Chaoborus,* 19.0; Chironomidae, 29.0; Sphaeriidae, 1.5; and Trichoptera, 5.3. On September 10, 1947, the poundage per acre was 2.73 (Table 3) and its percentage composition was: Oligochaeta, 19.8; *Hyalella,* 4.0; *Sialis,* 5.5; Ephemeroptera, 9.5; *Chaoborus,* 18.3; Chironomidae, 24.9; Amnicolidae, 10.6; and miscellaneous (Turbellaria, Odonata, Trichoptera, *Planorbis*), 7.3. The proportion of the dipterous larvae (*Chaoborus* and Chironomidae) corresponds very closely between the two surveys—48 percent in 1936 and 43.2 percent in 1947. The proportion of all the other organisms was decidedly different between the two surveys.

The probable explanation for these great differences between the two surveys lies in the small number of dredgings taken (62 in 1936 and 32 in 1947). With so few samples only the numerically abundant *Chaoborus* and Chironomidae could be estimated with reasonable accuracy. The fact that the proportion of these larvae was approximately the same at each time suggests that no great change occurred in the composition of the fauna in Redrock Lake over the 11-year period. In any event the sampling errors are such that it is difficult to assign percentage-composition values to the total weights of either survey. This fact was emphasized when the food of the eastern brook trout was studied by Baldwin (see footnote 1).

[2] Miller, R. B., 1937. A preliminary investigation of the bottom fauna of five Algonquin Park lakes. M.A. thesis, University of Toronto.

During the spring the insect group most utilized by these fish in Redrock Lake was Odonata. This could hardly have been predicted from the results of either the 1936 or 1947 surveys, in which Odonata formed a very small fraction. Thus the surveys failed to point out a stock of organisms which formed an important part of the food of the eastern brook trout.

Productivity of the Two Lakes

The average standing crop of bottom fauna.—Louisa Lake had an average bottom fauna, including the Oligochaeta, of 1.64 pounds per acre on August 5, and 2.15 pounds per acre on October 27. However, it was suggested that the Oligochaeta of August be excluded, and if this is done the seasonal change becomes 1.35 to 2.15 pounds per acre over the 12-week period—an increase of 59 percent by weight over the August value.

Seasonal change could also account for an increase from 1.5 to 2.73 pounds per acre between July 6 and September 10 in Redrock Lake. This change would represent an increase in weight of 82 percent over a 9-week period. Such a rate of change would be comparable to that found in Louisa Lake for the change in the latter lake, although less rapid, extended into the cool weather of the late fall when growth is slow.

These lakes are conveniently compared in October when the quantity of fauna approaches the maximal value. To make this comparison a certain percentage (say 20 percent on the assumption of a reduced growth rate in the autumn) should be added to the Redrock total of 2.73 pounds per acre to account for growth during the 7 weeks time between the two surveys. This addition would amount to 0.55 pound per acre and bring the Redrock Lake total up to 3.28 pounds per acre at the end of October. At the same time Louisa Lake had a total of 2.15 pounds per acre. Thus Redrock is believed to support a 52-percent heavier bottom fauna than Louisa Lake.

The amount of botom fauna in these two Algonquin Park lakes may now be compared with similiarily derived estimates for other lakes. However most published estimates are summer averages and should be regarded as submaximal. Rawson (1930) made such comparisons between seven lakes and obtained a range of 4.3 to 45.1 pounds per acre. Lake Ontario had the lowest and Lake Mendota the highest quantity of bottom fauna. Many later estimates could now be added to Rawson's list, but few would be less than those for the Algonquin Park lakes. The latter contain about the same amount of bottom fauna as the alpine lakes of western Canada. The average for four of these Rocky Mountain lakes was 2.68 pounds per acre (Rawson, 1942). Lake Athabaska with 2.9 pounds per acre (Rawson, 1947) and Great Slave Lake with 3.4 pounds per acre (Rawson, 1949) were also comparable to the Algonquin Park lakes in their amount of bottom fauna. Lower levels of productivity are represented by seven lakes in Penobscot and Hancock counties, Maine, at 1.2 pounds per acre (Fuller and Cooper, 1946), and Lake Arrowhead, California, an artificial lake with 0.91 pound per acre (Needham, 1937).

Although single values which express the average quantity of bottom

fauna in a lake may be convenient in generalized comparisons such as those above, Berg (1938) attached very little scientific value to their use. Berg regarded such values as too abstract from the actual conditions and recommended that the amounts of fauna at each depth be compared between lakes rather than the grand averages. This type of comparison is made in the following section.

The standing crop of bottom fauna at each depth.—The amounts of fauna at each depth of Louisa and Redrock Lakes (Table 6) were taken from the totals at the bottom of Tables 3, 4, and 5. They reveal that

TABLE 6.—*The weight of bottom fauna (pounds per acre) at each depth of Louisa and Redrock Lakes*

Lake and month of collection	Depth zone (feet)						
	0-15	15-30	30-45	45-60	60-75	75-150	150-210
Louisa (August).....	3.46	1.69	0.96	1.52	1.52	1.15	....
Louisa (October).....	4.74	2.50	1.81	0.89	1.78	1.31	2.15
Redrock (September)...	3.96	1.91	2.19	1.11	1.78	....	....

Louisa in October had a fauna equal to or greater than that of Redrock Lake in September in three of five depth zones. However, it was suggested that between September 10 and October 27 the Redrock Lake fauna could have grown in weight by 20 percent and then may have exceeded that of Louisa Lake at some of these depths. Certainly the fauna of Redrock Lake in September exceeded that of Louisa Lake in August in all but the 45- to 60-foot zone. It is concluded accordingly that there may have been little difference in the amounts of fauna at comparable depths between the two lakes at the same time of year.

The larger grand average for the fauna of Redrock Lake is explained by differences in the contour areas. In both lakes the amount of fauna in the 0- to 15-foot zone was almost twice that of any other zone. Also this zone had a relatively much larger area in Redrock Lake than in Louisa Lake. Therefore, the average fauna, weighted by area of zone, was greater for the former lake although the amounts of fauna at comparable depths were almost alike.

THE BOTTOM FAUNA IN RELATION TO THE LAKE TROUT

Martin (1952) analyzed the stomach contents of 205 lake trout from Louisa Lake and 214 from Redrock Lake. The average wet weights of insect remains per stomach were as follows from May to September, 1947; in Louisa Lake, 2.00 grams in May, 0.04 in June, 0.04 in July, 0.01 in August, 0.02 in September, and 0.00 in October; in Redrock Lake, 0.98 gram in May, 5.17 in June, 0.01 in July, 0.00 in August, and 0.00 in September.

Evidently insects were eaten most heavily during May in Louisa Lake and during June in Redrock Lake. At the time of maximal feeding upon insects the Redrock Lake trout obtained 2.6 times as much of this food as did

the Louisa Lake trout. Much of this feeding occurred in the highly productive 0- to 15-foot zone. This shallow zone comprised 44 percent of the surface area of Redrock Lake and 16 percent of that of Louisa Lake (Table 1). These relative areas are in a ratio of 2.7 to 1.0—almost the same as the maximal feeding ratio between the two lakes obtained above. A strong correlation is thus indicated between the maximal consumption of insect food by the lake trout and the availability of that food on a relative-area basis.

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Literature Cited

Berg, Kaj.
1938. Studies on the bottom animals of Esrom Lake. Kgl. Danske Vid. Selsk. Skr., Naturv.. Math. Afd. Vol. 9, No. 8, S. 1–255.

Borutsky, E. V.
1939. Dynamics of the total benthic biomass in the profundal of Lake Beloie (Russian; German summary). Arb. Limnol. Stat. Kossino. Vol. 22, pp. 196–218.

Fry, F. E. J.
1939. A comparative study of lake trout fisheries in Algonquin Park, Ontario. Univ. Toronto Stud., Biol. Ser. No. 46, Pub. Ont. Fish. Res. Lab. No. 58, pp. 7–69.

Fry, F. E. J., and V. B. Chapman
1948. The lake trout fishery in Algonquin Park from 1936 to 1945. Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 19–35.

Fuller, John L. and Gerald P. Cooper
1946. A biological survey of the lakes and ponds of Mount Desert Island, and the Union and Lower Penobscot River drainage systems. Maine Dept. Inland Fish. and Game, Fish Survey Rept., No. 7, pp. 1–221.

Martin, N. V.
1952. A study of the lake trout, *Salvelinus namaycush,* in two Algonquin Park, Ontario, lakes. Trans. Am. Fish. Soc. (1951), pp. 111–137.

Needham, P. R.
1937. A biological survey of Lake Arrowhead, California. Cal. Fish and Game, Vol. 23, pp. 311–328.

Rawson, Donald S.
1930. The bottom fauna of Lake Simcoe and its role in the ecology of the lake. Univ. Toronto Stud., Biol. Ser. No. 34, Pub. Ont. Fish. Res. Lab. No. 40, pp. 1–183.
1942. A comparison of some large alpine lakes in western Canada. Ecol., Vol. 23, pp. 143–161.
1947. Lake Athabaska. Fish. Res. Bd. Can., Bull. 72, pp. 69–85.
1949. Estimating the fish production of Great Slave Lake. Trans. Am. Fish. Soc., Vol. 77 (1947), pp. 81–92.

THE FOOD AND GROWTH RATE OF YOUNG WHITE BASS (*MORONE CHRYSOPS*) IN LAKE TEXOMA

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ABSTRACT

A study of the food and growth rate of the young white bass (*Morone chrysops*) was made from specimens collected between June and October, 1950 and 1951, in Lake Texoma, Texas. The major food organisms eaten by 125 young white bass in 1950 and 168 in 1951 were crustaceans (chiefly Cladocera and Copepoda), insects (chiefly Chironomidae), and gizzard shad. White bass ranging from 23 to 125 millimeters, standard length, ate all three organisms during the 5-month periods. Shad made up the largest percentage of volume of food eaten. Measurements from 349 young white bass in 1950 and 380 young fish in 1951 showed the 1951 fish grew much faster than those in 1950. The average standard length at the end of October 1950 was 74 millimeters, whereas on the same date in 1951, it was 126 millimeters. The accelerated growth of the 1951 white bass was due to the prolonged high-water level in the spring of that year and their continued heavy diet of fish.

INTRODUCTION

The presence of the white bass (*Morone chrysops*) in the Red River has been known for many years. With the construction of the Denison Dam and the impoundment of Lake Texoma, this species quickly became the most abundant game fish in the lake. A considerable amount of work has been done on the white bass of Lake Texoma, but little has been published. Weese (1951) reported on the age and growth of adult white bass in Lake Texoma. The present report on food and growth rate deals with the 1950 and 1951 broods of white bass from early June until late October.

Lake Texoma, impounded for flood control, hydroelectric power, and recreation, has an area of 93,080 acres at normal power-pool elevation of 617 feet above mean sea level. The dam is located on Red River between Grayson County, Texas, and Bryan County, Oklahoma, and was completed in 1944. The lake is subject to rapid and varied water-level fluctuations.

MATERIALS AND METHODS

Seining with a Common Sense minnow seine was initiated for young white bass in early May of both years. In 1950 the first white bass were taken June 3 and collections were continued with a ¼-inch-mesh bag seine until October 26. In 1951 collections were made from June 6 until October 25.

Roach (1943) reported that in Buckeye Lake, Ohio, samples of smaller fish were very difficult to obtain by seining because they apparently roam through open water and do not inhabit shallow shores as do most other game species. This same behavior was found during the daylight hours in the clear waters of Lake Texoma, but seining at night proved to be effective throughout the summer months. By September the lake level had fallen below most of the sandy beaches and seining was ineffective in the stumpy offshore areas. Fyke nets of ¼- and 1-inch mesh (bar measure) were used satisfactorily in 1951. The species of fish found associated with young white bass are listed in Table 1.

TABLE 1.—*Species of fish found associated with young white bass in Lake Texoma*

Species		Year collected	
Common name	Scientific name	1950	1951
Longnose gar	*Lepisosteus osseus*	x	x
Goldeye	*Hiodon alosoides*	x	x
Gizzard shad	*Dorosoma cepedianum*	x	x
Black buffalo	*Ictiobus niger*	...	x
Smallmouth buffalo	*Ictiobus bubalus*	x	x
River carpsucker	*Carpiodes carpio*	x	x
Carp	*Cyprinus carpio*	x	x
Silver chub	*Hybopsis storeriana*	x	x
Golden shiner	*Notemigonus crysoleucas*	x	...
Plains shiner	*Notropis percobromus*	x	x
Blacktail shiner	*Notropis venustus*	x	...
Chub shiner	*Notropis potteri*	x	x
Red shiner	*Notropis lutrensis*	x	x
Mimic shiner	*Notropis volucellus*	x	x
Plains minnow	*Hybognathus placita*	x	x
Fathead minnow	*Pimephales promelas*	x	...
Bullhead minnow	*Pimephales perspicuus*	x	x
Channel catfish	*Ictalurus lacustris*	x	x
Flathead catfish	*Pilodictis olivaris*	x	...
Mosquitofish	*Gambusia affinis*	x	x
Logperch	*Percina caprodes*	x	x
Largemouth bass	*Micropterus salmoides*	x	x
Longear sunfish	*Lepomis megalotis*	x	x
Bluegill	*Lepomis macrochirus*	x	x
White crappie	*Pomoxis annularis*	x	x
Brook silversides	*Labidesthes sicculus*	x	x
Freshwater drum	*Aplodinotus grunniens*	x	x

Since most of the collecting was done at night, all fish were preserved in a 10-percent solution of formalin and measured from 12 to 48 hours later. The standard and total lengths of each white bass were recorded to the nearest millimeter. The numbers of fish collected and measured were 349 in 1950 and 380 in 1951.

A representative sample of each collection was used for food analysis. Stomachs of fish, thought to contain food, were removed and opened. Food organisms were identified, and the volume of each organism was either measured by water displacement or recorded as a trace if less than 0.1 cubic centimeter. Only stomachs found to contain food were used in calculating the percentages of various food items found. The numbers of

stomachs opened were 125 in 1950 and 168 in 1951. The intestinal contents were not examined.

Food of Young White Bass

Young white bass were found to feed principally on crustaceans, insects, and fish (Tables 2 and 3; Fig. 1). Spiders were eaten in June and July of 1950, but none were found in 1951. Sigler (1949) found Entromostraca most abundant in stomachs of young white bass from Spirit Lake, Iowa. Ewers and Boesel (1936) also found crustaceans, especially Cladocera, predominant at Buckeye Lake, Ohio.

Crustaceans were found in stomachs of young white bass in each month of both years, but they made up a very small percentage of the volume of food. In terms of frequency they were a large part of the diet in 1950 when they occurred in 41 to 100 percent of the stomachs in the monthly samples. However, in 1951 they were found in only 4 to 31 percent of the stomachs. The only higher crustacean taken by the young white bass was the glass shrimp, *Palaemonetes,* found on two occasions, although this shrimp is rather abundant in Lake Texoma. The most common crustacean was *Cyclops,* with *Daphnia* next most abundant. Other crustaceans eaten included *Argulus, Diaptomus, Bosmina,* and an occasional phyllopod and ostracod.

Insects were less abundant than crustaceans with a maximum frequency of 75 percent recorded for August 1950. Diptera larvae (Chironomidae) were most plentiful and were found each month except in June 1950 and October 1951. Mayfly nymphs and damselfly adults formed the largest percentage of volume of insect food. Adult waterboatmen, beetle larvae, and adult ants and wasps were taken in small quantities.

The only vertebrate taken by young white bass was fish, of which small gizzard shad (*Dorosoma cepedianum*) was most abundant both in numbers and volume. Shad were taken in every month by all sizes of white bass, except in October 1950 when young shad were too large for the small white bass to prey upon them. In 1951, however, the growth of the white bass was fast enough for them to feed upon gizzard shad of the year throughout the entire period. It is possible that a large part of the unidentified fish remains was shad, but the organism was not classified as such unless identification was definite. Fish made up by far the greater part of the volume each month of the 2-year period and in all but two months was 100 percent of the measurable volume of food organisms. Brook silversides (*Labidesthes sicculus*), white crappie (*Pomoxis annularis*), and various cyprinids were also taken on occasion. No cannibalism was noted in either year.

The crappie taken in October 1951 were probably eaten by the white bass while both were trapped in the fyke net used for collection. Numerous additional white crappie, the same size as those eaten, were found alive in the net with the white bass. However, Sigler (1949) found that young

TABLE 2.—*Food of young white bass from Lake Texoma in 1950*
[Expressed as percentages of frequency of occurrence and total volume. L=larvae; N=nymph; A=adult]

Item	Month of collection			
	June	July	August	October
Details concerning samples studied				
Number of stomachs	39	38	27	21
Number containing food	37	29	20	20
Percentage containing food	95	76	74	95
Total volume food (cubic centimeters)	2.1	4.6	0.8	0.3
Length of fish[1]				
Average	37.1	56.6	70.0	69.8
Range	16-61	35-93	56-105	60-95
Percentage occurrence and volume of food items				
Food organism	Occurrence / Volume	Occurrence / Volume	Occurrence / Volume	Occurrence / Volume
Crustaceans	60 / Tr.[2]	41 / Tr.	55 / Tr.	100 / Tr.
Phyllopoda	... / ...	4 / Tr.	... / ...	... / ...
Cladocera	19 / Tr.	10 / Tr.	10 / Tr.	20 / Tr.
Copepoda	57 / Tr.	34 / Tr.	55 / Tr.	100 / Tr.
Ostracoda	... / ...	... / ...	... / ...	5 / Tr.
Malacostraca	... / ...	4 / Tr.	... / ...	... / Tr.
Arachnids	3 / Tr.	4 / Tr.	... / ...	... / ...
Insects	... / ...	41 / Tr.	75 / 25	50 / Tr.
Ephemeroptera (N)	... / ...	... / ...	10 / 25	... / ...
Odonata	... / ...	7 / Tr.	... / ...	5 / Tr.
Hemiptera (A)	... / ...	4 / ...	10 / Tr.	... / ...
Coleoptera (L)	... / ...	4 / ...	10 / Tr.	... / ...
Hymenoptera (A)	... / ...	10 / ...	... / ...	... / ...
Diptera (L)	... / ...	4 / ...	20 / ...	50 / ...
Insect Remains	... / ...	17 / ...	35 / ...	5 / ...
Fish	38 / 100	52 / 100	30 / 76	20 / 100
Gizzard shad	14 / 57	31 / 78	5 / Tr.	... / ...
Cyprinidae	3 / 14	4 / 17	5 / ...	5 / ...
Fish remains	22 / 29	17 / 4	20 / 76	15 / 100

[1] Standard length (millimeters) preserved
[2] Tr.=trace (less than 0.1 cubic centimeter)

TABLE 3.—*Food of young white bass from Lake Texoma in 1951*
[Expressed as percentages of frequency of occurrence and total volume. L=larvae; N=nymph; A=adult]

Item	Month of collection				
	June	July	August	September	October
Details concerning samples studied					
Number of stomachs	41	37	27	38	25
Number containing food	34	31	27	36	21
Percentage containing food	83	84	100	95	84
Total volume food (cubic centimeters)	0.5	14.4	37.6	37.1	71.6
Length of fish[1]					
Average	36.3	65.9	92.0	96.2	117.3
Range	23-55	37-108	55-133	56-155	70-165

Percentage occurrence and volume of food items

Food organism	Occurrence	Volume	Occurrence	Volume	Occurrence	Volume	Occurrence	Volume	Occurrence	Volume
Crustaceans	12	Tr.[2]	13	Tr.	4	Tr.	31	2	10	Tr.
Cladocera	3	Tr.	...	...	...	...	...	...	5	Tr.
Copepoda	12	Tr.	13	Tr.	4	Tr.	28	Tr.	10	Tr.
Malacostraca	...	...	...	...	...	...	3	2	...	...
Insects	33	Tr.	19	Tr.	4	Tr.	39	19	14	Tr.
Ephemeroptera (N)	...	...	6	Tr.	...	...	...	...	...	...
Odonata (A)	...	...	...	...	...	...	31	19	...	...
Hemiptera (A)	...	...	3	Tr.	...	...	...	...	...	...
Diptera (A)	6	Tr.	3	Tr.	...	...	31	Tr.	14	Tr.
Diptera (L)	30	Tr.	6	Tr.	4	Tr.	14	Tr.	...	...
Insect remains	...	...	3	Tr.	...	...	3	Tr.	...	...
Fish	84	100	97	100	96	100	78	80	86	100
Gizzard shad	66	100	33	72	81	96	44	64	33	43
Cyprinidae	...	...	3	Tr.	4	1	...	...	...	...
White crappie	...	...	...	...	...	...	...	...	38	52
Brook silversides	...	...	3	Tr.	...	...	...	...	...	...
Fish remains	18	Tr.	61	29	22	3	36	15	19	6

[1] Standard length (millimeters) preserved
[2] Tr.=trace (less than 0.1 cubic centimeter)

white bass fed to a small extent on the black crappie (*Pomoxis nigromaculatus*) in Spirit Lake, Iowa.

There appeared to be no correlation between the size of the white bass and the food consumed. In June 1951 fish measuring 23 and 24 millimeters, standard length, fed on copepods, chironomid larve, and gizzard shad. A combination of two and sometimes of all three of the organisms was found in the same stomach. In October of the same year, white bass ranging from 100 to 125 millimeters, standard length, were found to have eaten the same foods.

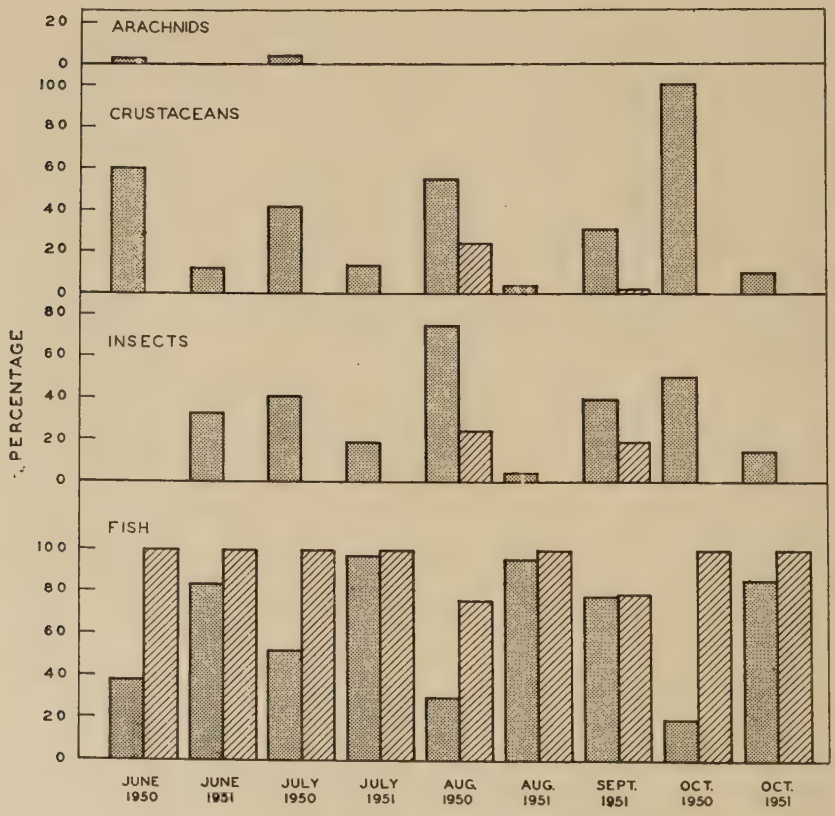

FIGURE 1.—Food of young white bass from Lake Texoma in 1950 and 1951, expressed as percentages of frequency of occurrence (dotted histograms) and total volume (lined histograms). No collections were made in September 1950.

RATE OF GROWTH

It is known that white bass prefer to spawn in running water. Each winter they congregate near the tributary streams of Lake Texoma and await a rise so that they can travel over the silt bars into the streams. However, in both 1950 and 1951 no rise came, and after waiting past their

normal spawning time, the fish returned down the lake and spawned on scattered wind-swept points. The first fry were collected in these areas in early June, and periodic collections were continued throughout October. The lengths of the white bass taken from these collections are shown in Table 4.

The 1950 growth progressed steadily until September, at which time it began to level off, but those bass spawned in 1951 continued to grow

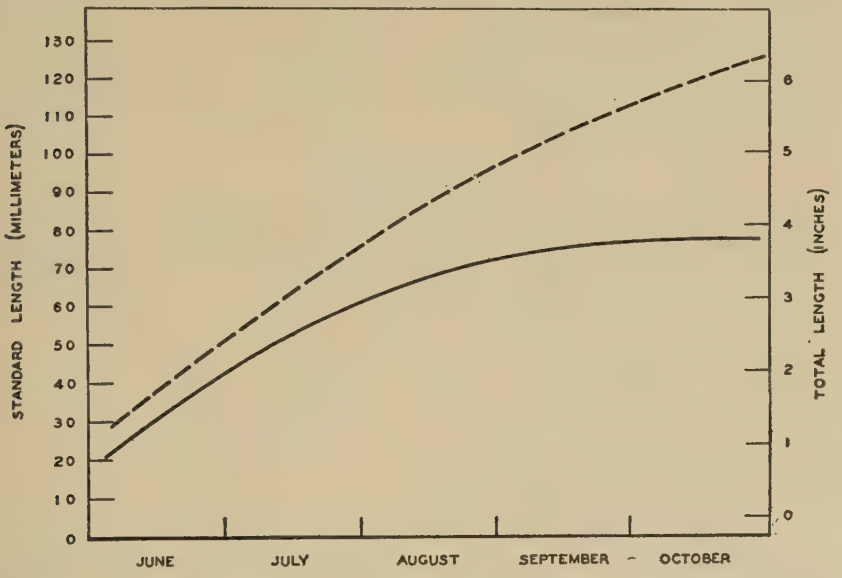

FIGURE 2.—Growth of young white bass in Lake Texoma in 1950 (solid line) and 1951 (broken line).

throughout the 5-month period (Fig. 2). In both years, the young fish had completed 50 percent of their growth for the period of observation by mid-July.

The average growth in the two years would be approximately 5 inches, total length, at the end of October. Sigler (1949) found young white bass to be approximately 4.3 inches long in October for the years he worked at Spirit Lake, Iowa, and Van Oosten (1942) reported Lake Erie bass to be 4.7 inches at the end of the first year of life. Apparently Lake Texoma white bass compare with those from Herrington Lake, Kentucky, where Tompkins and Peters (1951) found white bass to average 8.4 inches after 1 year of life.

Possible Factors Influencing Growth Rate

A possible explanation for the increased growth rate made by the white bass in 1951 over that of 1950 may be seen by comparing Figures 1 and 2. Fish formed the bulk of the diet of the bass in 1951 (never in less than 78

TABLE 4.—*Average lengths of young white bass of Lake Texoma on different dates of collection*

Collection	Number of fish	Standard length (millimeters)		Total length (inches)	
		Average	Range	Average	Range
1950					
June 3	12	21.3	17- 31	1.0	0.8-1.4
June 16	16	29.1	16- 42	1.4	0.7-2.0
June 30	89	45.0	22- 64	2.2	1.0-3.1
July 5	22	48.4	32- 70	2.4	1.5-3.4
July 13	30	45.2	35- 63	2.2	1.7-3.1
July 28	28	60.4	35- 92	3.0	1.8-4.6
August 25	111	59.4	45-107	3.0	2.2-5.3
October 5	28	64.8	59- 81	3.3	3.0-4.4
October 26	13	74.0	65- 97	3.7	3.3-4.6
1951					
June 6	47	29.3	23- 37	1.5	1.2-1.8
June 13	13	34.5	28- 42	1.7	1.4-2.0
June 24	10	46.4	32- 54	2.3	1.6-2.7
July 9	31	58.7	37- 80	2.9	1.8-3.9
July 20	34	61.6	45- 85	3.1	2.2-4.2
July 30	26	75.9	52-108	3.7	2.6-5.3
August 11	33	82.2	52-118	4.1	2.6-5.9
August 21	44	88.7	52-136	4.4	2.6-6.8
September 5	37	76.4	52-127	3.8	2.6-6.2
September 14	20	72.3	53-117	3.6	2.6-5.8
September 19	33	127.9	78-155	6.4	3.9-7.7
October 2	36	99.1	70-140	5.0	3.5-7.0
October 25	16	126.1	105-163	6.3	5.3-8.3

percent of the stomachs). Hunt and Carbine (1951) showed that an accelerated growth rate in northern pike (*Esox lucius*) is associated with the change to a vertebrate diet. The 1950 growth of the Lake Texoma white bass began to taper off in August when their diet changed back to insects and crustaceans.

Stroud (1948) believed that good growth occurs when water levels rise shortly after spawning. The level of Lake Texoma rose sharply from the winter low of 611.6 feet above sea level on May 18, 1951, to the season's high of 626.6 feet and continued above the normal elevation for 58 days. The 1950 water level made a short rise in May, but was rapidly brought back to near normal before June 1. Thus Lake Texoma white bass appear to provide another illustration of increased growth following high water levels.

Acknowledgments

I wish to thank sincerely the biologists on the staff of the Inland Fisheries Division of the Texas Game and Fish Commission for their assistance in both field work and laboratory analysis, and to acknowledge the cooperation of the personnel of the Denison Project, U. S. Corps of Engineers, and of the Hagerman National Wildlife Refuge, U. S. Department of the Interior, Fish and Wildlife Service.

Literature Cited

Ewers, Lela A., and M. W. Boesel
1935. The food of some Buckeye Lake fishes. Trans. Am. Fish. Soc., Vol. 65, pp. 57–69.

Hunt, Burton P., and William F. Carbine
1951. Food of young pike, *Esox lucius*, and associated fishes in Peterson's Ditches, Hougton Lake, Michigan. Trans. Am. Fish. Soc., Vol. 80 (1950), pp. 67–83.

Roach, Lee S.
1943. Buckeye Lake white bass. Ohio Jour. Sci., Vol. 43, No. 6, pp. 263–266.

Sigler, William F.
1949. Life history of the white bass, *Lepibema chrysops* (Rafinesque), of Spirit Lake, Iowa. Iowa Agr. Exp. Sta., Res. Bull. 366, pp. 203–244.

Stroud, Richard H.
1948. Growth of the basses and black crappie in Norris Reservoir, Tennessee. Jour. Tenn. Acad. Sci., Vol. 23, pp. 31–99.

Tompkins, William A., and Mercer M. Peters
1951. The age and growth of the white bass, *Lepibema chrysops*, of Herrington Lake, Kentucky. Ky. Div. Game and Fish, Fish. Bull. 8, 12 pp.

Van Oosten, John
1942. The age and growth of the Lake Erie white bass, *Lepibema chrysops* (Rafinesque). Pap. Mich. Acad. Sci., Arts, and Letters, Vol. 27 (1941), pp. 307–334.

Weese, A. O.
1951. Age and growth of *Lepibema chrysops* in Lake Texoma. Proc. Okla. Acad. Sci., Vol. 30, pp. 45–48.

AN EXPERIMENT IN THE ARTIFICIAL CIRCULATION OF A SMALL MICHIGAN LAKE [1]

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ABSTRACT

The water of the hypolimnion of West Lost Lake, a small Michigan trout lake, was pumped to the surface with a centrifugal pump and discharged into the epilimnion during a 10-day period in midsummer. The volume of water displaced was 20.7 percent of the lake volume. As pumping progressed the thermocline lowered steadily and the thickness of the hypolimnion decreased. At the conclusion of pumping, the volume of the epilimnion had increased by 49.9 percent and the water of the hypolimnion had been displaced to the surface. The mean water temperature of the lake remained essentially constant during the experiment. In a 3-week period following pumping, thermal conditions of the lake did not change appreciably. During pumping, conductivity and alkalinity increased in the epilimnion and in the bottom water, and the dissolved oxygen of the bottom water increased rapidly. The addition of bottom water increased the total phosphorus of the epilimnion by 2.8 micrograms per liter during the first 48 hours of pumping. Thereafter, phosphorus decreased to approximately the level encountered before pumping. An eight- to tenfold increase in the volume of phytoplankton of the epilimnion took place during the period of pumping. The volume of phytoplankton and the weight of seston remained high for a 3-week period following the experiment.

INTRODUCTION

During the past two decades, the Michigan Department of Conservation has sponsored a research program aimed at providing trout fishing in inland lakes. The results of field surveys have indicated that a comparatively

[1] Contribution from the Institute for Fisheries Research.

large number of lakes are suitable for trout in temperature and in the amount of dissolved oxygen. Certain of these lakes are small, rather unproductive, stratified bodies ranging in size from 3 to 25 acres. Removal of warm-water fish by chemical treatment and subsequent stockings with trout have made many of these lakes attractive to sportsmen. Attempts to improve the fish harvest by fertilization have shown that the addition of fertilizer may lead to serious oxygen depletion during the winter months (Ball, 1950) and also may decrease the volume of water suitable for trout by raising the level of the thermocline (Tanner).[2]

The present study was undertaken to determine (1) if artificial circulation of the water of small lakes could be achieved by pumping the bottom water to the surface and (2) what influence the addition of the stagnant water of the hypolimnion to the photosynthetic zone in midsummer might have on the production of plankton. Such a procedure appears to have an advantage over fertilization in that it should increase rather than decrease the trout habitat by cooling and deepening the epilimnion. It is also apparent that the risk of winter oxygen depletion should be small since no nutrient material would be added to increase the production of the lake to the extent achieved by fertilization; the object being to utilize more efficiently nutrient already present but which under normal conditions is not made available in the photosynthetic zone until late fall.

The influence that vertical mixing of water masses has upon the distribution of nutrients and upon plankton production of the sea has been recognized for many years (Nathansohn, 1906). Spring and fall maxima of plankton in the sea are correlated with water movements which enrich the photosynthetic zone with nitrogen and phosphorus (Harvey, 1945). Spring and fall maxima in plankton are also known in fresh water lakes (Birge and Juday, 1922). The occurrence of such spring and fall maxima in stratified inland lakes has been noted frequently (Welch, 1952; Allee, *et al.*, 1949). There are, however, few data indicating that well defined spring and fall maxima occur in small inland lakes. Pennak (1946) could find little evidence in the literature for spring and fall maxima, except in large and relatively deep lakes and rivers. Spring plankton pulses frequently consist of diatoms and may be related more to the quantity of silica available than to the availability of other nutrients (Lund, 1950). Midsummer blooms of the Cyanophyta are characteristic of many of the small inland lakes (Hutchinson, 1944). Autumnal maxima are reported less frequently. Strøm (1930) suggested that the nutritive salts of the hypolimnion brought into the trophogenic waters at the fall overturn are not used by plankton in lakes at high latitudes because of temperature and light conditions at this season.

Unquestionably a variety of conditions exists in small inland lakes which can modify or destroy seasonal rhythms characteristic of the sea and large inland waters. Yoshimura (1932) found a midsummer plankton

[2] Tanner, Howard A. Experimental fertilization of Michigan trout lakes. 186 pp., 1952. [Typewritten thesis; Michigan State College]

maximum in Takasuka Pond, a shallow eutrophic lake, which he believed was sustained in part by nutrients brought into the epilimnion from the hypolimnion by wind action. He also noted a positive correlation between the quantity of plankton and the inflow of stream water. Unstratified lakes may or may not show fall and spring maxima. It is frequently stated that a large littoral area (over which water circulates freely throughout summer stagnation) favors high production (Strøm, 1930). Many of the Michigan trout lakes are unusually deep in relation to their area. Thus a large percentage of the water volume is below the upper limit of the thermocline. This situation restricts circulation of nutrients during summer stagnation and results in a decreased productivity. It is of interest therefore to determine whether or not artificial circulation during summer will to any degree counteract this inherent morphometric limitation.

After the field work of the present study was in progress, Grim (1952) published an account of an attempt to circulate the water of a small German lake in midsummer by pumping the warm surface water to the bottom of the hypolimnion. After 180 hours of pumping, the temperature of the bottom water had increased 5°C. During this period, the temperature of the surface water increased from 22°C. to 26°C. as a result of solar heating. Water movements initiated within the hypolimnion by pumping brought about an increase in thickness of the hypolimnion, and produced a sharp temperature gradient within the thermocline, but apparently had little influence upon the water of the epilimnion.

The lake selected for the experiment was West Lost Lake, one of a group of six trout lakes located in Otsego and Cheboygan counties, Michigan. These lakes lie within the Pigeon River Trout Research Area, administered by the Institute for Fisheries Research, and have been used extensively during the past 20 years as experimental lakes for fishery investigations (Eschmeyer, 1938; Ball, 1950). In 1948, West Lost Lake was poisoned to remove fish. In 1949, it was stocked with brown trout and fertilized with commercial fertilizer containing 10 percent nitrogen, 6 percent phosphoric acid, and 4 percent potassium. In 1949, 400 pounds of fertilizer were added during the summer, and in 1950 an additional 300 pounds were applied (Tanner).[3] In the fall of 1950, the lake was again poisoned and the fish removed. At the time of our experiment, July 1952, the lake did not contain fish. However, the plankton and bottom fauna apparently had recovered from the effects of the poisoning in 1950.

West Lost and four of the other Pigeon River lakes lie in basins possessing an unusual degree of radial symmetry. All of the lakes are landlocked. The water surface is approximately 40 feet below the surrounding terrain, and the slope to the water is very abrupt (Fig. 1). A recent collapse of a section of shore of one of the lakes (Section 4 Lake) has led to the belief that the lakes are limestone sinks (Tanner),[4] although the sedimentary rock of the area apparently is covered by several hundred feet of glacial outwash and drift.

[3] See footnote 2.
[4] See footnote 2.

The lake has an area of 3.6 acres and a volume of 3,151,000 cubic feet. It has a mean depth of 20.3 feet and a maximum depth of 42 feet. The shoreline and subsurface contours are almost circular in outline and are

FIGURE 1.—Pumping equipment in operation at West Lost Lake.

spaced uniformly down the entire slope of the basin (Fig. 2). Features of the aquatic vegetation and bottom fauna have been discussed by Tanner.[5] Barrett [6] discussed the bottom soils of the lake and their relationship to the alkalinity of the water, and the adsorption and regeneration of phosphorus during the fertilization experiment described above.

[5] See footnote 2.

[6] Barrett, Paul H. Effects of alkalinity on adsorption and regeneration of phosphorus in natural lakes. 129 pp., 1952. [Typewritten thesis; Michigan State College]

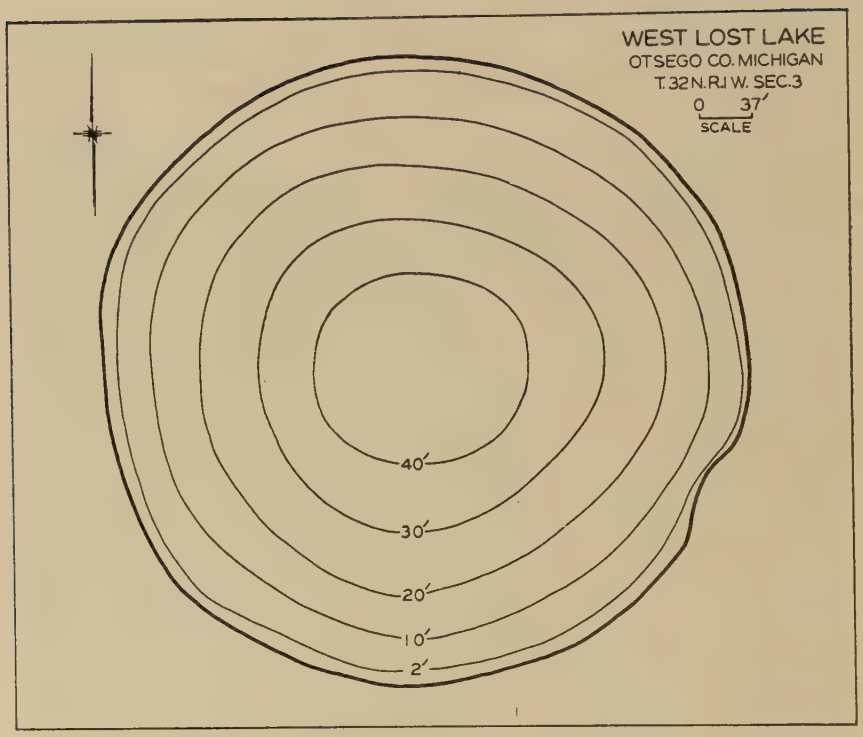

FIGURE 2.—Hydrographic map of West Lost Lake.

METHODS

The equipment used in the pumping was a self-contained unit consisting of a centrifugal pump with a rated capacity of 25,000 gallons per hour powered by a four-cylinder gasoline motor (Fig. 1). The unit was mounted on a trailer. The surface of the lake was considerably below the surrounding terrain and the slope to the lake edge very steep. This condition necessitated the construction, with a bulldozer, of an access ramp from the higher land to the water's edge. Iron irrigation pipe, 4 inches in diameter, was used for both intake and discharge lines. The intake end was first placed 36 feet below the surface near the center of the lake. After 24 hours of pumping the pipe was lowered to the bottom of the lake, which at the intake end was 39 feet. No screen was used on the intake since the lake bottom was free of trash. With the intake in this position, the discharged water showed traces of bottom sediments for about 5 minutes of operation. Thereafter it was as clear as the water collected in other parts of the lake at the 39-foot depth. The discharge pipe was suspended on floats constructed of oil drums, and the end emptied into a floating barge which

served to break up the force of the flow and spread out the discharge water in a thin sheet at the lake surface. The discharge was at the south end of the lake, approximately 60 feet from shore at a point where the water was 14 feet deep.

At the start of pumping on July 29, temperature observations were made in the vicinity of the discharge in an effort to determine the fate of the bottom water at the lake surface. At this time, water leaving the discharge was 51.0°F., and the temperature of the surface water was 75.9°F. With the Foxboro resistance thermometer, it was possible to trace the cold, bottom water as a well defined current moving horizontally just below the surface for a distance of from 2 to 5 feet from the discharge barge. At greater distances, the horizontal velocity of the cold current decreased and vertical mixing increased. Lenses of colder water 1 to 2 feet in thickness and 2 to 4 feet below the surface were encountered sporadically around the outflow at a distance of from 6 to 10 feet. Here the temperature varied between 67° and 72°F. At a greater horizontal distance, it became increasingly difficult to detect temperature differences in the water mass, indicating that the outflow was losing thermal identity rapidly. The temperature measurements gave no indication of density currents returning water to the deeper parts of the lake but suggested instead that the water was mixed rather thoroughly within 4 or 5 feet of the surface.

Pumping was started on July 29 and continued until August 8. The pump was in operation continuously except for shutdowns for refueling and motor maintenance. The total actual running time was 244 hours. The calibrated capacity of the pump was 20,000 gallons per hour. The calculated volume of water pumped is 652,400 cubic feet. Temperature of the water at the discharge was consistently 5°F. higher than the temperature of the lake at the intake level, indicating that some water was entering the pipe through leaks at the joints above the intake. Efficiency could therefor have been improved slightly by securing better seals at the pipe joints.

Temperatures were taken at 1-foot intervals with two Foxboro resistance thermometers. The underwater photometer described by Greenbank (1945) was used to measure light penetration. Subsurface readings were made at 3-foot intervals and a surface reading was usually made after two successive subsurface readings. A Klett-Summerson photoelectric colorimeter was used for turbidity measurements and for phosphorus and iron determinations. Conductivity was measured with a portable battery-operated conductivity bridge. Oxygen, carbon-dioxide, and inorganic and total phosphorus were determined by the methods outlined by Ellis, Westfall, and Ellis (1946). To determine the percentage of dissolved organic phosphorus, samples were first filtered through three layers of No. 50 Whatman filter paper with a filter pump. All phosphorus determinations were made in duplicate. In most analyses duplicates agreed within 1 or 2 scale divisions of the colorimeter. When discrepancies were greater, contamination was suspected and additional determinations were made. Inorganic iron was determined by the Dipyridyl method as outlined in Standard

Methods of Water Analysis (American Public Health Association, 1949). Samples for chemical analysis were collected at the surface and at depths of 6, 13, 20, 36, 39, and 41 feet. The 20-foot depth was omitted on July 27 and July 31 but was added thereafter because of the increase in depth of the epilimnion.

Net plankton collections were made with a 10-liter plankton trap. Samples for seston determinations were collected with a Juday bottle. Two 1-gallon samples collected at each depth were centrifuged in a Foerst centrifuge at a flow rate of 1 gallon every 40 minutes. Ash-free dry weight of seston was determined by drying the centrifuged seston at 60°C., weighing on a sensitive balance, ashing in a muffled furnace at 600°C., and reweighing. Plankton counts were made from a modified Sedgwick-Rafter cell which could be used under a 4-millimeter microscope objective. Estimates of the mean number of the predominant species within the cell were made according to the procedure recommended by Serfling (1949). A 95-percent confidence interval was calculated for each mean. The average volume of colonies of each species was calculated by measuring approximately 50 randomly selected colonies.

Water Movements

The principal changes in the water masses of the lake as pumping progressed were (1) a steady increase in the depth of the epilimnion, (2) sinking of the thermocline at a nearly constant rate, and, as would be expected, (3) a decrease in the thickness of the hypolimnion as the bottom water was displaced (Fig. 3). The upper limit of the thermocline lowered from 13 feet to 25 feet. The volume of the epilimnion was thus increased by 49.9 percent. A major portion of this increase apparently was due to the displacement of the bottom water to the surface. This is indicated by the steady downward shift of the thermocline during the period of pumping (Fig. 3). The observed increase in volume was 12.0 percent greater than the theoretical increase based upon the estimated volume of bottom water pumped. The additional increase appears to be due to displacement of the thermocline by thermally- and wind-induced water movements. Water movements arising from a combination of the cooling effect of the inflowing bottom water and from convective and radiational cooling of the surface waters brought about a marked increase in depth of the epilmnion on the nights of July 29, 30, and 31 (Fig. 3). On these nights air temperatures fell below 40°F. and steam fog developed over the lake surface. Similar thermally induced water movements were apparent during the period from August 3 to August 6.

The upper limit of the thermocline was displaced vertically through a frustum of the lake basin whose volume approximates the volume of water pumped from the intake. The 68° isotherm descended through a frustum whose volume is 18 percent of the lake volume. This figure approximates the volume of water pumped from the bottom (20.7 percent). Isotherms below 65° showed progressively greater negative deviation from this theo-

retical displacement, suggesting greater vertical mixing. Below the intake (39 feet) temperature changes were small. At the 40-foot depth the temperature increased 2.0°F. and at 41 feet only 1.2°F. Eddy diffusion initiated by the flow at the intake apparently was responsible for these temperature changes. Sinking of the isotherms to the intake level led to the establishment of a sharp temperature gradient below the intake; thus mixing of this stratum was made more difficult.

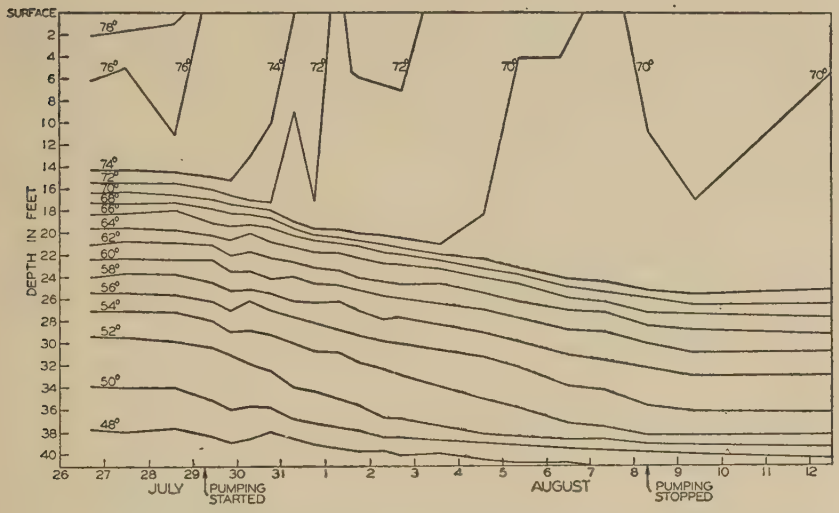

FIGURE 3.—Depth of water at which various temperatures (°F.) were found in West Lost Lake, July 27-August 12, 1952.

The mean temperature of the lake water was 67.9°F. on July 29 and 67.2° on August 8. The small change indicates that pumping had distributed heat within the lake basin but had not brought about losses or gains in heat. Following pumping, essentially uniform thermal conditions were retained during the remainder of August. The epilimnion remained approximately isothermal, and the depth of the thermocline was unchanged. Unfortunately no observations were made in September. By October 5 the lake was isothermal to a depth of 35 feet. The temperature at this time was 58.2°F.

Pumping was discontinued after 10 days since it was apparent that all of the bottom water rich in phosphorus above the intake had been displaced. Water entering the intake at this time was similar chemically and in temperature to water originally present in the thermocline. Doubling the pumping time would have displaced the volume of water remaining between the upper limit of the thermocline and the intake, but would not have increased the concentration of phosphorus in the photosynthetic zone.

Turbidity and Transparency

Prior to the experiment, the turbidity of water collected between the surface and the 29-foot level was 3 p.p.m. or less. Between 29 feet and 36 feet, turbidity increased from 2 to 12 p.p.m., and between 36 feet and the maximum depth there was a further increase of 2 p.p.m. Suspended detritus gave a pink cast to water samples from 36 feet and below when viewed in direct light. This particulate material could be removed by filtration with a coarse filter, or by centrifuging with a plankton centrifuge. Centrifuging removed 33 p.p.m. of organic matter from water collected at 39 feet. Microscopic examination showed that this material was chiefly plankton detritus in which trichomes of *Oscillatoria* sp. were predominant. Soon after the start of the pumping a decrease in turbidity occurred below 29 feet as the deeper water containing suspended material was replaced by transparent water of the thermocline. By August 4, turbidity was 3 p.p.m. or less in all parts of the lake except in the stratum below the level of the water intake.

The addition of the turbid bottom water to the epilimnion caused no measurable decrease in transparency. Measurements made with the underwater photometer indicated little change during the period from July 29 to August 3. However, a sharp decrease occurred between August 3 and August 5 (Fig. 4). On August 5, a 12-percent decrease in percentage of surface light transmitted to the 3-foot level and a decrease of from 10 to 15 percent in light transmitted to other levels of the epilimnion was observed. A logarithmic plot of the transparency data of August 3 and August 5 shows that the greatest decreases in transparency were above 12

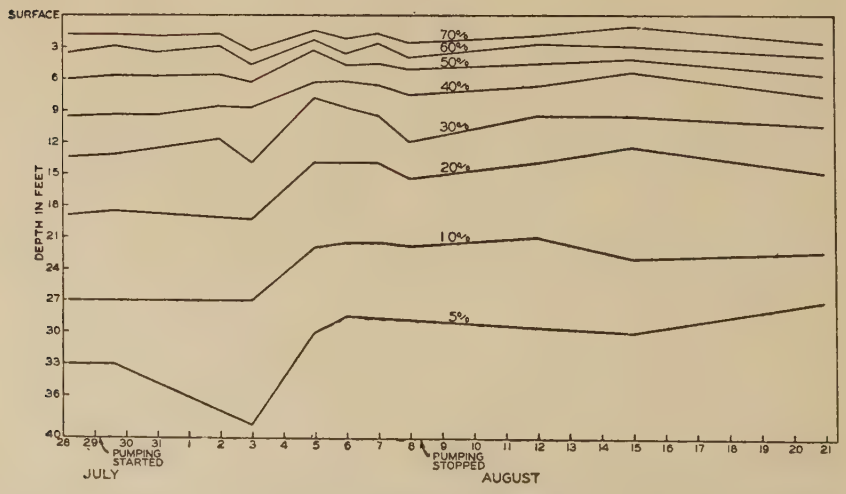

Figure 4.—Depth of penetration of various percentages of surface light in West Lost Lake, July 28-August 21, 1952.

feet although smaller changes are indicated to a depth of 36 feet. The time and depth of those changes in transparency are correlated with major increases in phytoplankton. The increases in volume of phytoplankton between July 31 and August 5 (Fig. 8) were greatest in the upper 13 feet although a smaller increase occurred at 29 feet.

Oxygen, Alkalinity, and Conductivity

As the bottom water was displaced, the oxygen-rich water of the thermocline moved progressively lower into the lake basin. Isopleths of dissolved oxygen in the lake basin during pumping show a slope comparable to that of lines of equal temperature (Fig. 5). However, a somewhat more rapid downward movement of dissolved oxygen is suggested by the presence of

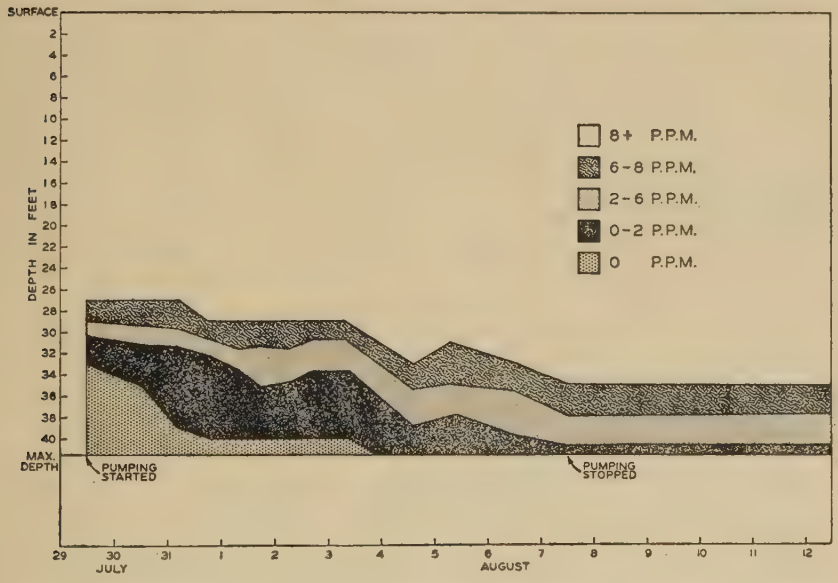

Figure 5.—Depth of water for various ranges of concentration of dissolved oxygen in West Lost Lake, July 29-August 12, 1952.

traces of oxygen at the intake level (39 feet) after only 48 hours of pumping. This change apparently was produced by eddy currents arising from the convergent flow at the water intake rather than the sinking of the thermocline water. Traces of oxygen were present at the bottom of the lake (41 feet) after 5 days of pumping, and the oxygen had increased to 1.8 p.p.m. at the 39-foot level on the fifth day. When pumping was discontinued, oxygen values greater than 5 p.p.m. were to be found in all parts of the lake basin with the exception of the stratum below the intake.

The increases in alkalinity and specific conductivity that appeared at the

29- and 36-foot levels during the first 48 hours of pumping (Fig. 6) suggest that a movement of bicarbonate took place from the mud into the water. Alkalinity and conductivity decreased somewhat at 29 and 36 feet

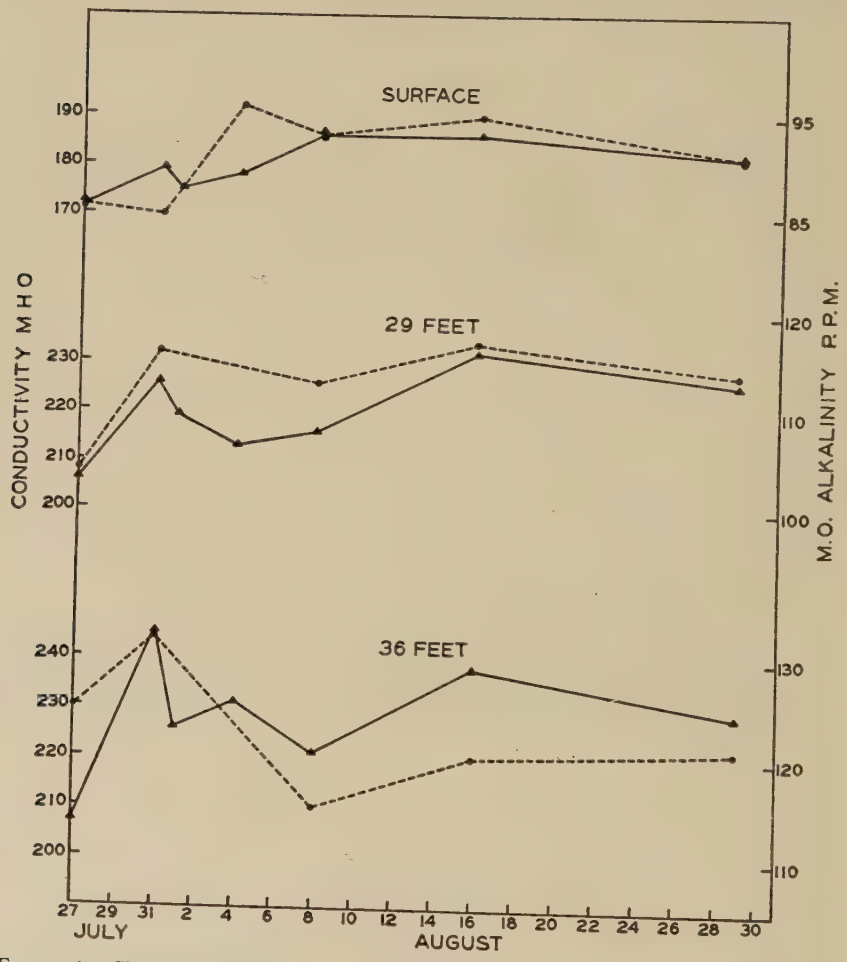

FIGURE 6.—Changes in conductivity in reciprocal megohms (solid lines) and methyl-orange alkalinity in p.p.m. (broken lines) in West Lost Lake, July 27-August 30, 1952.

during the remainder of the pumping period as water at these depths was gradually replaced by thermocline water lower in dissolved salts. The inflow into the epilimnion of bottom water of high alkalinity and containing aggressive carbon dioxide led to a gradual increase in the conductivity and alkalinity of the epilimnion. On August 4 alkalinity at the surface and 13-foot depths was 15 p.p.m. greater than observed on July

29. Phenolphthalein alkalinity increased throughout the epilimnion between July 31 and August 4. On August 8 phenolphthalein alkalinity was encountered for the first time at a depth of 29 feet, and a further large increase was observed at the surface, 13 feet and 20 feet. This increase in carbonate coincided with increases in phytoplankton in the epilimnion and thermocline.

Phosphorus

The distribution of phosphorus within the lake during the experiment and for a 3-week period following the cessation of pumping is shown in Figure 7. On July 27 total phosphorus varied only slightly between the surface and the 29-foot depth. From 29 to 41 feet the total phosphorus concentration increased from 7 to 31 micrograms per liter. Filtration of

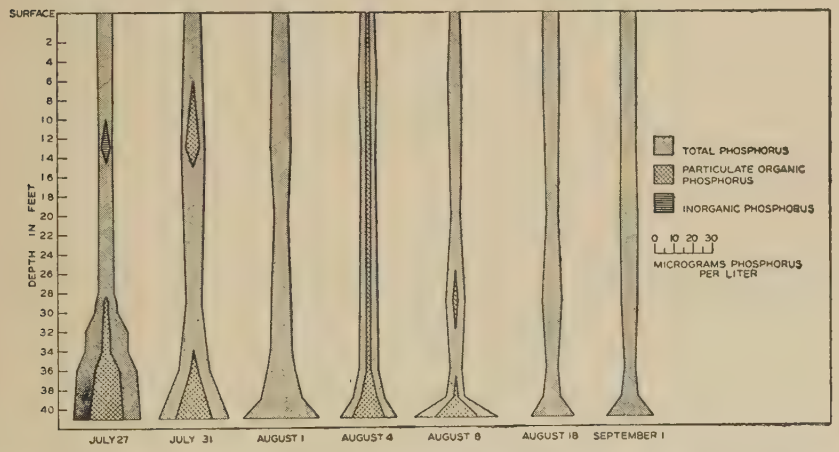

Figure 7.—Vertical distribution of phosphorus in West Lost Lake, July 27-September 1, 1952. The width of each graph represents total phosphorus. The fraction of particulate organic phosphorus and inorganic phosphorus is indicated by cross-hatching. Analyses for particulate organic phosphorus were not made on August 1 and 18, or on September 1.

water samples removed 40 percent of the phosphorus present at 36 feet and 51 percent of that present at 41 feet, indicating that the suspended plankton detritus contributed heavily to the phosphorus content of the bottom waters. The limited variation in phosphate of the filtered fraction below 36 feet, shows that the increase in total phosphorus below this level was due principally to the phosphorus of suspended detritus.

Approximately 52 percent of the available hypolimnetic phosphorus was transferred to the surface during the first 3 days of pumping. The first clear indication of increased biological activity appeared after 7 days of pumping. The steady removal of phosphorus from the bottom water is indicated in Figure 7. On August 4, the concentration of phosphorus at the

intake had fallen to 16 micrograms per liter, and 80 percent of the available phosphorus had been removed. By August 8, phosphorus at the intake was not appreciably greater than at several points within the epilimnion. The mean total phosphorus of the epilimnion increased by 2.8 micrograms per liter during the first 48 hours of pumping but thereafter decreased steadily. On August 4, it was approximately equal to the amount present at the start of the experiment, and by August 8 it was slightly below this value (Table 1). A theoretical increase of 3.35 micrograms per liter would be expected on August 8 on the basis of quantity of hypolimnetic phosphorus added to the epilimion. Thus it is apparent that a loss of both

TABLE 1.—*Mean total phosphorus of epilimnion water from July 27 until the fall overturn*
[The phosphorus averages were calculated from samples at two depths on July 27 and July 31, and from four depths on the remaining dates. Averages were weighted for the volume of water of the corresponding strata]

Date	Mean total phosphorus (micrograms per liter)	Date	Mean total phosphorus (micrograms per liter)
July 27	7.46	August 8	6.01
do. 31	10.26	do. 18	7.42
August 1	9.48	September 1	8.15
do. 4	7.48	October 6	7.45

dissolved and sestonic organic phosphorus took place between July 31 and August 8. Small quantities of particulate organic phosphorus were detected at the 13-foot depth on July 31, throughout the epilimnion and thermocline on August 4, but only at the 29-foot depth on August 8. In other samples the difference in total phosphorus between filtered and unfiltered samples was so small as to give no reliable indication of sestonic organic phosphorus. The transitory appearance of particulate phosphorus in the water mass suggests that the particulate phosphorus introduced at the surface was rapidly lost by sedimentation and that little if any of the added phosphorus was directly incorporated into the plankton.

Inorganic phosphorus was present in detectable quantities in only one sample collected during the course of the investigation. This sample was from the bottom of the epilimnion (13 feet) on July 27. In all other samples, readings of the colorimeter were never more than one or two scale divisions greater than readings made on distilled-water blanks to which chemical reagents had been added. Since the error involved in reading the colorimeter in this portion of the concentration scale approaches this difference between unknown and blanks, little can be said regarding the concentration of inorganic phosphorus except that it never exceeded a concentration of 1 microgram per liter. The absence of detectable quantities of either dissolved or sestonic inorganic phosphorus at any depth indicates that little inorganic phosphorus had been regenerated from the mud by reductive processes as noted in Esthwaite Water by Mortimer (1941). It also indicates that little if any inorganic phosphorus was transferred to

the epilimnion in the form of ferric or calcium phosphate as occurs in other lakes at time of the fall overturn (Hutchinson, 1941; Einsele, 1936, 1938). None of the iron determinations made on July 27 by the Dipyridyl method were positive for either ferric or ferrous iron indicating that the concentration of inorganic iron was less than 20 micrograms per liter.

Plankton

The phytoplankton of the lake at the time of the experiment was of the cyanophycean type. Over 95 percent of the algae present consisted of colonies of *Chroococcus dispersus* (Keissl.). *Sphaerocystis Schroeterii* (Chodat) was second in abundance but did not make up more than 4 or 5 percent of the volume in any sample. Colonies of *Coelastrum* sp., *Nephrocytium* sp., *Crucigenia rectangularis* (A. Braun), *Oöcystis* sp., and *Dinobryon divergens* (Imhof) were present but not common. The species composition of the phytoplankton changed little during the experiment and during the succeeding 3-week period. The increase in the volume of phytoplankton cells between July 28 and August 5 (Fig. 8) is in part due to an increase in the average size of colonies of *Chroococcus,* but principally to an increase in the number of colonies. At 13 feet the average

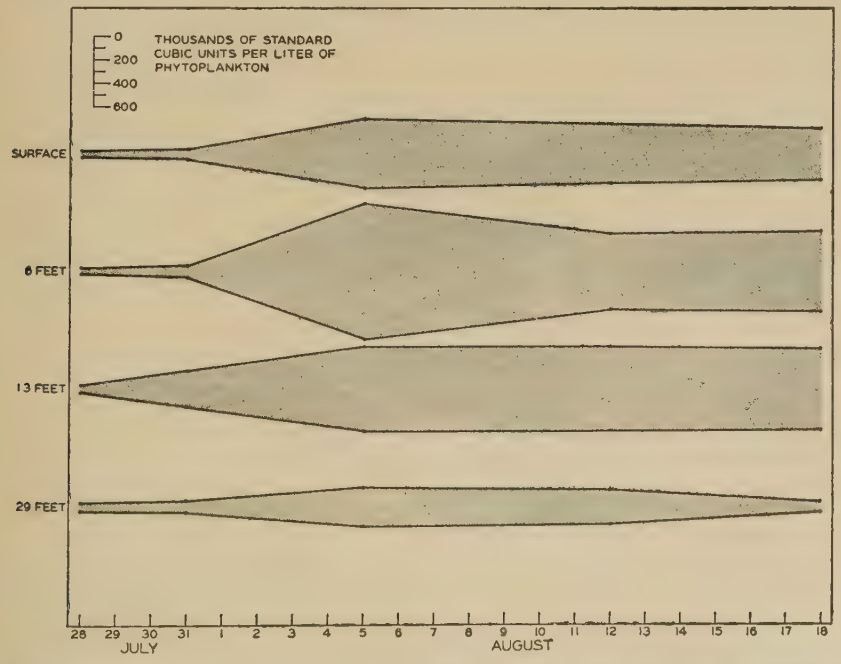

Figure 8.—Changes in volume of phytoplankton in West Lost Lake, July 28-August 18. Volume of phytoplankton is represented in standard cubic units. One standard cubic unit $= 8 \times 10^{-6}$ cubic millimeters.

volume of *Chroococcus* colonies increased by 50.5 percent between July 28 and August 5. During this period the number of colonies increased from 945 to 10,509 per liter. Between August 5 and August 12 the average colony size decreased slightly, but the number of colonies increased further to 14,184 per liter. After this initial phase of rapid growth, phytoplankton production remained sufficiently high to sustain a standing crop in the epilimnion 8 to 10 times greater than that which was present on July 28.

Data on both plankton and transparency suggest that the pulse began in the lower part of the epilimnion on July 31 and spread to the surface water. A fivefold increase in plankton volume occurred between July 28 and 31 at 13 feet. Increases at 6 feet and at the surface were small and not significant statistically. Small decreases in transparency took place between 9 and 15 feet during this period, although the transparency of the upper part of the epilimnion did not decrease significantly until August 3.

Confidence limits of counts at 6 feet on August 5 do not overlap limits of counts at the surface and 13 feet. This fact indicates a definite concentration of plankton at the 6-foot depth. On August 12 and 18, however, the 95-percent confidence limits of counts at the surface, 6 feet, and 12 feet overlapped considerably, indicating that the algae were more uniformly distributed.

The increase in the volume of living algae between July 31 and August 5 raised the mean ash-free dry weight of seston of the epilimnion by 31.2 percent. A decrease occurred in the weight of seston at 29 feet, although the volume of phytoplankton cells increased. This situation was apparently due to the displacement of detritus-laden water of the hypolimnion by water from the thermocline, low in detritus but containing more living algae. The seston of September 1 again showed a predominance of *Chroococcus*. The average weight of seston had increased substantially over that on August 12 (Table 2). On October 6, the lake was isothermal down to 35 feet, although the temperature of the water remained high

TABLE 2.—*Mean ash-free dry weight of seston of epilimnion*

[Mean values were calculated from samples at three depths on each date and weighted for volume of water of corresponding strata]

Date	Mean seston (milligrams per liter)	Date	Mean seston (milligrams per liter)
July 31	17.6	August 18	23.2
August 6	23.1	September 1	34.1
do. 12	22.6	October 6	24.7

(58.2°F.). The mean weight of seston on this date was approximately the same as between August 6 and August 18. However, the phytoplankton differed qualitatively in that *Crucigenia* and *Sphaerocystis* were more abundant than *Chroococcus*.

An observation of interest during the pumping experiment was an apparent increase in periphyton growth on submerged logs and detritus in

shallow water. The growth was particularly conspicuous on the wooden floor of the barge used at the end of the discharge pipe. Here a bright green carpet of periphyton developed on the detritus from the hypolimnion which had settled to the bottom of the barge. The periphyton consisted chiefly of masses of *Sphaerocystis,* but included *Chroococcus, Spirogyra, Lyngbya,* and numerous diatoms.

Direct comparison of the phytoplankton during this study with that during normal years and during the period of fertilization is not possible. The estimates of phytoplankton by Tanner [7] before fertilization in 1948 and after the addition of fertilizer (1949–1950) were made from Secchi-disk readings. The Secchi-disk observation of August 12 (4 days after pumping) was 15 feet, 8 inches, and was less than any reading recorded by Tanner in 1948 except in early June. It was well below his average of 23.7 feet for the entire summer of 1948, although greater than his summer average of 13.8 feet for the second summer of fertilization (1950). These limited data suitable for comparison suggest that the transparency following the plankton increase was less than that to be expected without artificial fertilization, although greater than the average after the addition of 300 pounds of commercial fertilizer during the summer. It is also noteworthy that in 1948 Secchi-disk readings increased rapidly during late August and early September. Following pumping in 1952 there was no increase in transparency in late August. This fact suggests that the stimulus provided by the pumping sustained phytoplankton growth during the period in which there is normally a decrease in photosynthesis.

The principal Entomostraca of the lake were *Daphnia longispina.* Small numbers of *Ceriodaphnia pulchella, Bosmina longirostris,* and *Diaptomus oregonensis* were recorded. The number of Entomostraca recorded from duplicate 10-liter plankton-trap samples was highly variable. It was thus difficult to make comparisons of catches on different dates and at different depths. The data, however, do not indicate an increase in zooplankton comparable to the phytoplankton pulse noted above.

Comparison with Events of Fall Overturn

The experiment simulated qualitatively, although not quantitatively, many of the events taking place in small lakes during the autumnal overturn. The water masses of greatest physical and chemical dissimilarity were mixed and water movements were initiated which made possible the exchange of electrolytes between the bottom soils of a large part of the lake basin and the superimposed water. Oxygen was introduced into the hypolimnion and the aggressive carbon dioxide and dissolved and suspended substances of the bottom waters were brought into the photosynthetic zone. Certain environmental conditions, however, were decidedly different from those normally attending the fall circulation. Temperatures in the upper water remained high and the total quantity of heat in the entire lake re-

[7] See footenote 2.

mained nearly constant. Little precipitation and little surface runoff entered the lake during this period. The amount of solar radiation reaching the lake surface was greater and more nearly constant at this season than in the fall. If seasonal climatic changes were largely eliminated from the events of the autumnal overturn, it would then appear that the biological changes observed during the experiment were directly or indirectly related to the mixing of the water masses which occurs during the normal seasonal overturn. The increase in phytoplankton appears to have been a direct response to artificial circulation, since the observed increase in algae did not appear to be characteristic of this or of the other Pigeon River lakes at this season, except immediately after the addition of fertilizer. The observed phytoplankton pulse differed from spring and fall pulses in other lakes (Welch, 1952; Birge and Juday, 1922) in that it involved chiefly a single species and that the usual succession of predominant species following the initial pulse did not take place. This species, *Chroococcus dispersus,* was predominant before pumping was started. The absence of changes in the ratio of predominant to subordinate forms following the pulse is surprising. Hutchinson (1944) suggests that minor changes in the nutrient level may bring about succession of one species by another, because of slight physiological advantage in competition for nutrient.

Artificial Circulation as a Management Technique

The transitory increase in total phosphorus of the epilimnion, followed by a rapid return to the level encountered at the start of the experiment suggests that sedimentation and perhaps adsorption by bottom materials and littoral vegetation removed phosphorus from the system until it returned to an equilibrium value. From their study of the rate of decrease of radioactive phosphorus from Bluff Lake, Nova Scotia (Hayes *et al.,* 1952) postulated an active exchange of phosphorus between the water and the participating lake solids (plants and animals, as well as bottom muds) and suggested that the phosphorus added to lakes in fertilization experiments is rapidly lost to the solids until an equilibrium is established. At equilibrium, there is a small net increase which is usually only a small fraction of the initial increase after fertilization. The total phosphorus concentration at this time represents the participating phosphorus of the new equilibrium level. They suggested that the disappearance of phosphorus when stratification is broken up in the autumn may be due to a rapid equilibration of the phosphorus brought into the upper water with the living organisms rather than solely to the precipitation of inorganic phosphorus upon oxidation in the epilimnion as suggested by Einsele (1938). The rapid return to approximately the initial level in West Lost Lake suggests that some process of this type tended to stabilize the phosphorus level. Since the initial increase in phosphorus was only 38 percent, the equilibrium value would probably not be sufficiently above the initial level to be detected.

The quantity of phosphorus added to the epilimnion by pumping is

small when compared to the quantity used in fertilization experiments. The theoretical addition was 239 grams of phosphorus, which is equivalent to the phosphorus contained in 43 pounds of commercial fertilizer containing 6 percent P_2O_5. Since there are few data to indicate that pumping caused more than a temporary increase in the total quantity of phosphorus in the epilimnion, it must be assumed either that phosphorus was not a nutrient limiting the growth of *Chroococcus,* or that the added phosphorus in some way increased the availability of the organic phosphorus in the epilimnion without increasing the total quantity present in the water. The heavy periphyton growth on the bottom of the discharge barge suggests that the detritus and organic matter brought up from the bottom was more susceptible to breakdown and release of nutrient than organic matter originally present in the epilimnion. A slow release of phosphate from the detritus that settled to the bottom in the littoral zone may have sustained an increase in plankton for a considerable period, even though an increase in soluble phosphate in the water was not evident. Lund (1950) cited the work of Mackereth (private communication) who found that *Asterionella* cells can remove phosphate from water at concentrations below 0.06 microgram per liter. Very likely *Chroococcus* also can remove and store inorganic phosphorus at a concentration below that which could be detected by chemical analysis. Thus, the data do not negate the possibility that phosphorus was a nutrient utilized in the plankton pulse, although they throw little light upon the mechanism involved.

The experiment demonstrates that artificial circulation of many smaller trout lakes is possible during the summer at least to an extent sufficient to displace the water of the hypolimnion to the surface. Although the production of plankton was not stimulated to the extent achieved during fertilization, the treatment may have increased the carrying capacity of the lake for fish beyond that which could be safely achieved by artificial fertilization. At the conclusion of the experiment, all of the water of the lake above the intake was within the range of temperature and concentration of oxygen suitable for trout. The plankton and bottom organisms of a major portion of a lake basin were thus made available. The procedure overcomes objections raised to artificial fertilization of natural lakes (Hasler, 1947), such as hastening eutrophication, creating obnoxious odors and increasing weed growth. Further studies however will be necessary to evaluate the usefulness of this technique fully.

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Literature Cited

Allee, W. C., Orlando Park, Alfred E. Emerson, Thomas Park and Karl P. Schmidt
1949. Principles of animal ecology. W. B. Saunders Co., Philadelphia, xii + 837 pp.

American Public Health Association
1946. Standard methods for the examination of water and sewage. 9th Ed., New York, xvii + 286 pp.

Ball, Robert C.
1950. Further fertilization of natural lakes in Michigan. Trans. Am. Fish. Soc., Vol. 78 (1948), pp. 145–155.

Birge, Edward A., and Chancey Juday
1922. The plankton. I. Its quantity and chemical composition. Wis. Geol. and Nat. Hist. Surv., Bull. 64, Sci. Ser. No. 13, 222 pp.

Eschmeyer, R. William
1938. Further studies of perch populations. Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 23 (1937), pp. 611–631.

Ellis, M. M., B. A. Westfall, and M. D. Ellis
1946. Determination of water quality. U. S. Dept. Inter., Fish and Wildlife Serv. Research Rept. No. 9, 122 pp.

Einsele, Wilhelm
1936. Über die Beziehungen des Eisenkreislaufs zum Phosphatkreislauf im eutrophen See. Arch. f. Hydrobiol., Bd. 29, S. 664–686.
1938. Über chemische und kolloidchemische Vorgänge in Eisen-Phosphat-Systemen unter limnochemischen und limnogeologischen Gesichtspunkten. Arch. f. Hydrobiol., Bd. 33, S. 361–387.

Greenbank, John
1945. Limnological conditions in ice-covered lakes, especially as related to winterkill of fish. Ecol. Monogr., Vol. 15, pp. 343–392.

Grim, Julius
1952. Ein See wird umgepflügt. Allg. Fisch.-Ztg., Jahrg. 77, No. 14, S. 281–283.

Harvey, H. W.
1945. Recent advances in the chemistry and biology of sea water. Cambridge Univ. Press, viii + 164 pp.

Hasler, A. D.
1947. Eutrophication of lakes by domestic drainage. Ecology, Vol. 28, pp. 383–395.

Hayes, F. R., J. A. McCarter, M. L. Cameron, and D. A. Livingston
1952. On the kinetics of phosphorus exchange in lakes. Jour. Ecology, Vol. 40, pp. 202–216.

Hutchinson, G. Evelyn
1941. Limnological studies in Connecticut: IV. Mechanism of intermediary metabolism in stratified lakes. Ecol. Monogr., Vol. 11, pp. 21–60.
1944. Limnological studies in Connecticut: VII. Examination of the supposed relationship between phytoplankton periodicity and chemical changes in lake water. Ecology, Vol. 25, pp. 3–26.

Lund, J. W. G.
1950. Studies on *Asterionella formosa* Hass. II. Nutrient depletion and the spring maximum. Jour. Ecology, Vol. 38, pp. 1–14, 15–25. [Reprinted in 2 parts]

Mortimer, C. H.
1941. The exchange of dissolved substances between mud and water in lakes. Jour. Ecology, Vol. 29, pp. 280–329.
1942. The exchange of dissolved substances between mud and water in lakes. (continued) Jour. Ecology, Vol. 30, pp. 147–201.

Nathansohn, Alexander
1906. Über die Bedeutung vertikaler Wasserbewegungen für die Produktion des Planktons im Meere. Abhandl. d. Kgl. Sächs. Ges. d. Wissensch., Math. Phys. Kl., Bd. 29, S. 355–441.

Pennak, Robert W.
1946. The dynamics of fresh-water plankton populations. Ecol. Monogr., Vol. 16, pp. 339–356.

Serfling, Robert Elton
1949. Quantitative estimation of plankton from small samples of Sedgwick-Rafter-cell mounts of concentrate samples. Trans. Am. Micros. Soc., Vol. 68, pp. 185–199.

Strom, Kaare Munster
1930. Limnological observations in Norwegian lakes. Arch. f. Hydrobiol., Bd. 21, S. 97–124.

Welch, P. S.
1952. Limnology. Second ed., McGraw-Hill, New York, xii + 538 pp.

Yoshimura, S.
1932. Seasonal variations in content of nitrogenous compounds and phosphate in the water of Takasuka Pond, Saitama, Japan. Arch. f. Hydrobiol., Bd. 24, S. 155–176.

THE FISHERY IN LAKE WAPPAPELLO, A FLOOD-CONTROL RESERVOIR ON THE ST. FRANCIS RIVER, MISSOURI

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ABSTRACT

Lake Wappapello, an impoundment on the St. Francis River in southeastern Missouri, was created in 1941 by the Corps of Engineers, U. S. Army, as part of the flood-control program for the lower Mississippi River. At conservation-pool level (355 feet, Mean Gulf Level) the reservoir has a surface area of approximately 6,000 acres and more than 50 percent of the lake is less than 5 feet deep. At times of high water the area may be expanded to 23,100 acres.

Prompted by the decline in fishing success, particularly for black bass, the Missouri Conservation Commission launched a series of investigations in 1948. The results of 4 years of fish-population surveys made by means of nets, seines, and rotenone are presented. White crappie and carp consistently were the most abundant species in the nets. These fish constituted, respectively, 52 and 20 percent by number of the total net catch. Rotenone sampling in two small coves in 1951 indicated that the backwater areas support an average standing crop of 273 pounds of fish per acre. The buffalos were the most abundant (122.4 pounds per acre) followed by carp (26.8 pounds per acre). Adult black bass were recovered at the rate of 7.6 pounds per acre. Nine percent of the average standing crop consisted of game fish of usable size.

Data on age composition of the population and rate of growth of 8 species are offered as further evidence of the status of the population. In general, the calculated growth rates of these fishes may be considered as average compared with the rates of growth of the same species in other Missouri impoundments except for bluegill and gizzard shad, which grow slowly.

Creel-census data acquired during the period 1946–1951 show that white crappie comprised over 80 percent of the catch in each of the 6 years. From the intensive creel census initiated in 1951, it was estimated that fish were harvested at the rate of 6.3 pounds per acre. Fishing pressure was estimated to be 21 hours per acre. Only 1 percent of the fishing was done with artificial lures.

In a discussion of management procedures it is suggested that a commercial fishery be considered for this reservoir to utilize the non-game fishery resource which is not harvested adequately at the present time.

INTRODUCTION

Many fishery investigators in recent years have explored problems of population censusing and analysis. Although accurate estimates of the size and structure of fish populations are highly desirable for management purposes, they are difficult to obtain for large bodies of water. A number of approaches to the problem have been tried but frequently it is necessary to analyze data gathered from several sources in order to evaluate the fishery.

Tarzwell (1942) utilized data from nets, seines, sport and commercial fishing, and rotenone treatment to determine the relative abundance of fishes in Wheeler Reservoir, Tennessee. Moyle, Kuehn, and Burrows (1950) discussed the fish populations of Minnesota lakes from data obtained over a period of years by use of seines, gill nets, hoop nets, and a creel census. Thompson (1950) compared results obtained with seines, nets, and rotenone in Grand Lake, a large reservoir in Oklahoma, and included an analysis of age and growth in the population investigations for that impoundment. Whereas in the natural lakes of Minnesota seining produced the most reliable population data, in large artificial impoundments of Tennessee and Oklahoma the use of rotenone in backwater areas appeared to give best results.

In Missouri reservoirs no single method of conducting a census of fish populations is adequate; therefore a number of methods are employed. The results of population surveys made on Lake Wappapello between 1948–1951 are discussed here and an analysis is made of creel-census data collected since 1946.

Lake Wappapello was created in 1941 when the Corps of Engineers, U. S. Army, impounded the St. Francis River near Wappapello, Missouri, where the river emerges from the Ozark Highlands. This reservoir was constructed as part of the flood-control program for the lower Mississippi River. At conservation-pool level (355 feet Mean Gulf Level) Lake Wappapello has a surface area of 5,700 acres, but this area is increased to 23,100 acres at flood-pool elevation of 395 feet.

The 1,310-square-mile drainage area of this impoundment lies in the Ozark Highlands. The St. Francis River originates in the Ozark Plateau at an elevation of about 1,280 feet. From its source to where it emerges from the upland at Wappapello Dam the river flows 125 miles through steep, rocky terrain of which about 65 percent is in forest. Over half of the area lies in Clark National Forest. Below the dam the river meanders through low, flat terrain for 309 miles until it enters the Mississippi River above Helena, Arkansas.

At conservation-pool level the reservoir is relatively shallow. Except in the former river and tributary channels, the maximum depth is only 15 feet and at least half of the lake is not more than 5 feet deep. Brush and floating logs are cleared periodically from the shoreline and backwater areas. Aquatic vegetation is scarce and is not likely to become well established because of fluctuations in water level and the disturbance of the mud by bottom-feeding fishes.

Since 1943, water levels were manipulated for malaria control except during periods of high water. The water level was fluctuated weekly as much as 0.5 foot from June 1 to October 1. The elevation was dropped gradually from 359 to 356 during this 4-month period.

During the waterfowl hunting season, the lake level was stabilized at elevation 358.5. Extensive plantings of a cultivated variety of wild millet

were made in the shallow flats near the head of the main body of the reservoir to attract migratory waterfowl.

Fishing was considered excellent in Lake Wappapello during its first 4 years when good catches of black bass were reported.[1] In later years angling success, especially for black bass, declined. To obtain a better understanding of the fishery resource in this impoundment the Missouri Conservation Commission began a series of investigations in 1948, 7 years after the reservoir was established.

Methods of Sampling Fish Population

Fish were collected with nets, seines, and rotenone in the main body of the lake. Test-netting was carried out over a period of 10 days in late summer or fall in each of the 4 years. The gear differed somewhat from one year to another but was consistent in that gill nets and hoop nets were used each time.

Gill nets of single mesh sizes and graded meshes were used. The mesh size of both types ranged from 1 to 2 inches (bar measure) and all were of 6-foot depth. The nets were 150 feet to 300 feet long. Hoop nets made either of 1¼- or 2½-inch-mesh webbing (bar measure) had a 5-foot front hoop, and were baited with cottonseed cake.

Trammel nets were fished only in 1948. In 1950 and 1951 a 3-foot and a 4-foot trap net similar to the net described by Crowe (1950) were employed with considerable success.

Small fish were collected with 15-, 25-, and 100-foot seines. A 25-foot, ¼-inch-mesh bag seine was used extensively in 1950 and 1951.

Rotenone was applied to a 1-acre cove in 1949. In 1951, a similar census was made of 0.79 acre of the same cove. The area was blocked off with a line of rotenone in 1949 but seines were used as a block in 1951. A second area (1.3 acres) was censused in like manner in 1951. Fish were recovered for 3 days following each application of the rotenone. In 1951, tagged fish were introduced into the census areas to test the effectiveness of recovery by this method.

Net Catches

The number and weight of each species of fish taken in the nets are listed in Table 1. The names are taken from the list of names published by the American Fisheries Society (1948). White crappie and carp were the most abundant species in each year's collection. These two fish constituted, respectively, 52 and 20 percent by number of the total catch. White crappie were the most abundant of the fishes taken in all types of netting gear except the trammel nets. Carp were captured in all of the nets but the number taken probably was influenced by the baited hoop nets. By weight, carp comprised nearly 50 percent of the total net catch in each of

[1] Largemouth bass (*Micropterus salmoides*) and spotted bass (*M. punctulatus*).

the 4 years of the survey. A similar netting program in other Missouri reservoirs in 1950 suggests that carp were most abundant in Lake Wappapello.

In each of the 4 years of test-netting, non-game fish comprised over 60 percent of the population by weight. These fishes were represented by 14 species in addition to carp.

Nets are selective by species and size, but data from net catches are useful as indicators of trends provided uniform gear is fished under similar conditions. The hoop-net catches for carp and white crappie were adequate for an analysis of this kind.

TABLE 1.—*The total number and weight (in pounds) of each species of fish collected from Lake Wappapello in nets, 1948-1951*

[Names marked with an asterisk are considered to be game fish by the Missouri Conservation Commission]

Species	Number	Weight
Lepisosteus productus. Spotted gar	12	31.4
Lepisosteus platostomus. Shortnose gar	18	52.1
Amia calva. Bowfin	2	8.3
Dorosoma cepedianum. Gizzard shad	191	91.8
Megostomatobus cyprinella. Bigmouth buffalo	12	44.0
Ictiobus niger. Black buffalo	20	36.2
Ictiobus bubalus. Smallmouth buffalo	48	125.8
Minytrema melanops. Spotted sucker	3	0.7
Moxostoma aureolum. Northern redhorse[1]	42	46.0
Moxostoma erythrurum. Golden redhorse	1	0.7
Moxostoma duquesnei. Black redhorse	1	0.8
Placopharynx carinatus. River redhorse	1	1.0
Cyprinus carpio. Carp	612	1,409.6
Ictalurus lacustris. Channel catfish*	152	178.1
Pilodictis olivaris. Flathead catfish	1	35.0
Micropterus punctulatus. Spotted bass*	1	0.3
Micropterus salmoides. Largemouth bass*	7	12.8
Lepomis machrochirus. Bluegill*	20	2.7
Pomoxis annularis. White crappie*	1,554	604.5
Pomoxis nigromaculatus. Black crappie*	37	22.2
Morone chrysops. White bass*	62	39.0
Aplodinotus grunniens. Freshwater drum	196	122.0
Totals	2,993	2,865.0

[1] This fish has been described as the subspecies *Moxostoma aureolum pisolabrum*, pealip shorthead redhorse (Trautman and Martin, 1951).

Table 2 shows the average number and weight of these fishes taken per 24-hour hoop-net set each year. The rate of catch of carp in the hoop nets was identical in 1948 and 1949. However, the catch approximately doubled in number and weight in 1950. The number taken in 1951 was less than that of 1950, but the mean weight per fish in 1951 was larger than the average weight of carp taken in preceding years. The increase in the number of carp in 1950, and the increase in their average weight in 1951 suggests that one year class dominated the carp population both years.

Three times as many white crappie were captured in the hoop nets in 1950 as in 1948 and 1949. A pronounced increase of young crappie in

the population in 1950 was indicated by the smaller average weight of the individual fish. The 1950 rate of catch of crappie in the hoop nets was repeated in 1951 but the average weight of the individual fish was greater. Again, the data suggest the presence of a strong year class.

TABLE 2.—*The average number and weight of carp and white crappie per 24-hour hoop-net set and the average weight per fish for each period of test netting in Lake Wappapello*

Item	1948	1949	1950	1951
Carp				
Number per set	1.8	1.8	3.8	2.8
Pounds per set	4.2	3.9	7.7	9.7
Average weight per fish (pounds)	2.3	2.2	2.0	3.0
Total number of carp	181	75	156	120
White crappie				
Number per set	1.3	1.4	4.0	4.1
Ounces per set	12.0	9.7	19.5	32.2
Average weight per fish (ounces)	9.2	7.0	4.8	6.2
Total number of crappie	129	58	168	170

ROTENONE CENSUS

A population census of backwater areas was made in September, 1949 and 1951, by means of rotenone.[2] The areas were relatively shallow. The maximum depths were 7 to 10 feet at reservoir elevation 357.95 and water temperature ranged from 71° to 76°F.

The use of a toxicant for collecting fish is the best available technique for obtaining quantitative estimates of fish populations in shallow areas, provided the limitations of the method are considered. This method is most effective in relatively shallow waters and even then a complete recovery of fish is not possible. Brown and Ball (1943), Ball (1947, 1948), Krumholz (1950), and others have demonstrated that many fish are lost. In Lake Wappapello only 35 percent of 53 tagged fish that were put in the census areas were recovered. No adjustment was made for inefficient recovery. Since 46 of the 53 tagged fish were crappies, applying a correction to the data for other species would be invalid and, to be consistent, the values for crappie also were not corrected. The figures on recovery given here are no doubt substantially below the true values but we do not know how badly the population was underestimated.

Fish were recovered in 1951 at the average rate of 273 pounds per acre. The composition of the backwater population by species, size group, number, and weight is shown in Tables 3 and 4. Only 9 percent (26.8 pounds per acre) of the population consisted of game fish of catchable size. Black bass of catchable size were recovered at an average rate of 7.6 pounds per acre, pan fish (white crappie and bluegill) at 7.1 pounds per acre, and channel catfish at 12.1 pounds per acre (Table 3).

[2] Details of the 1949 census are not included because the area was not blocked off with seines as in 1951. Fish were recovered from the cove at the rate of 99.8 pounds per acre in 1949.

In contrast, these coves contained 180.1 pounds per acre of large non-game fish—6 times the weight of large game fish (Table 4). The buffalos made up 67 percent of the weight of non-game fish (122.4 pounds per acre); carp comprised 14 percent (26.8 pounds per acre). Excluding gizzard shad, these areas supported 114 catchable-size fish per acre of which 32 were game fish.

TABLE 3.—*The population of game fishes in the backwaters of Lake Wappapello in 1951 as indicated by the rotenone census in two coves with a total surface area of 2.09 acres*
[Length measurements are expressed as total length in inches]

Species	Fish of catchable size			Fish of intermediate size		Fingerling fish	
	Minimum length	Number per acre	Pounds per acre	Range in length	Number per acre	Maximum length	Number per acre
Largemouth bass	10	7	6.6	5- 9.9	14	4.9	85
Spotted bass	10	1	1.0	5- 9.9	1	4.9	3
Bluegill	6	5	0.8	4- 5.9	11	3.9	1,427
White crappie	7	10	6.3	4- 6.9	3	3.9	40
Channel catfish	12	9	12.1	5-11.9	10	4.9	1
Green sunfish[1]	6	..	....	4- 5.9	5	3.9	52
Warmouth[2]	6	..	....	4- 5.9	2	3.9	32
White bass	9	..	....	5- 8.9	1	4.9	3
Totals	..	32	26.8	.....	47	...	1,643

[1] *Lepomis cyanellus*
[2] *Chaenobryttus coronarius*

Fish of intermediate size presumably would have been available for the creel in 1952. These fish were recovered in moderate numbers only. Largemouth bass were taken at the average rate of 14 fish per acre. Freshwater drum, longear sunfish, and spotted suckers were the only non-game fish represented in this size group.

The population of fingerlings was dominated, numerically, by bluegill and gizzard shad. Young-of-the-year of most of the non-game fish were not present in the backwater areas. Of the 88 black bass fingerlings recovered per acre, 85 were largemouth bass. The dominance of all sizes of largemouth bass over spotted bass in the backwaters of Lake Wappapello is clearly shown in Table 3.

Population of Small Fishes

The minnow population of Lake Wappapello is comprised of few species. The Mississippi blacktail shiner, *Notropis venustus,* is probably the most abundant of the minnows, followed by the bullhead minnow, *Pimephales perspicuus,* and the common emerald shiner, *Notropis atherinoides.* If the piscivorous fishes were dependent only upon minnows for sustenance their existence would be precarious. The bulk of the forage fishes consisted of brook silversides, *Labidesthes sicculus,* young gizzard shad, and small sunfishes. In midsummer these fishes seem to provide an abundant source

of food. Possibly their abundance accounts for poor hook-and-line fishing during the summer months.

Measuring the success of reproduction of the game fishes and important non-game fishes is of value in management. In 1950 and 1951 special attention was given to the number of these fingerlings in the hauls made with a 25-foot bag seine.

A comparison with data for all other large Missouri impoundments suggests that largemouth bass reproduction in Lake Wappapello was aver-

TABLE 4.—*The population of non-game fishes in the backwaters of Lake Wappepello in 1951 as indicated by the rotenone census in two coves with a total surface area of 2.09 acres*[1]
[Length measurements are expressed as total length in inches]

Species	Fish of catchable size			Fish of intermediate size		Fingerling fish	
	Minimum length	Number per acre	Pounds per acre	Range in length	Number per acre	Maximum length	Number per acre
Freshwater drum	10	14	12.1	5- 9.9	36	4.9	33
Longear sunfish[2]	6	..	.....	4- 5.9	16	3.9	555
Gizzard shad	7	93	15.3	4- 6.9	..	3.9	1,221
Spotted sucker	12	3	1.6	5-11.9	25	4.9	.....
Bigmouth buffalo	12	26	65.2	5-11.9	..	4.9	.....
Smallmouth buffalo	12	19	51.6	5-11.9	..	4.9	.....
Black buffalo	12	3	5.6	5-11.9	..	4.9	.....
Carp	14	15	26.8	7-13.9	..	6.9	.....
Redhorse spp	12	2	1.9	5-11.9	..	4.9	.....
Totals	..	175	180.1	.....	77	...	1,809

1 Not included in the table were 215 minnows and darters per acre, 395 unidentified small sunfishes per acre, and 486 orangespotted sunfish (*Lepomis humilis*) per acre
2 *Lepomis megalotis*

age in 1950 and somewhat above average in 1951. In neither year, however, could it be viewed as outstanding. Reproduction of spotted bass was extremely limited in both years. Their fingerlings were outnumbered by fingerling largemouth bass 4 to 1 in 1950; 10 to 1 in 1951. Reproduction of white crappie was exceptionally good in 1951. These fingerlings averaged 8.7 fish per seine haul in 1951 as compared to 1.4 fish per seine haul in 1950. This spawning was better than in any of the other large Missouri reservoirs. White bass reproduction was slight both years in comparison with other game species, but bluegill fingerlings were abundant. Except for gizzard shad, young-of-the-year of non-game fishes were not often taken in the seine hauls.

The success of reproduction of the species that spawn in shallow water depends not only upon temperature and water conditions in impounded waters but also upon the stability of the water level during the spawning season. There is always a possibility that a whole year class may be eliminated by a rapid drop in the water level at a critical time.

Between April 1 and July 1, water levels in Lake Wappapello were fairly stable in 1948, 1949, and 1951. However, in April and May of

1950 there were two distinct high-water periods followed by 10-foot drops over periods of 24 and 10 days. It is possible that the spawning success of fishes such as carp, buffalo, black bass, and crappie was curtailed as a result. Reproduction of white crappie and largemouth bass was better in 1951 than in 1950. Data for other species are inconclusive.

Age and Rate of Growth

The calculated growth rates of 8 species of fish in Lake Wappapello are presented in Table 5 (see Footnote 1 of the table for method of calculation). The rates of growth for the several species are considered about

Table 5.—*The average calculated total length in inches attained at the end of each year of life by 8 species of fish in Lake Wappapello*[1]

Species	Number of fish	Average total length (inches) at end of year of life									
		1	2	3	4	5	6	7	8	9	10
White crappie	468	3.0	7.0	10.2	11.7	12.6	13.3	13.9	....	....	....
Largemouth bass	100	5.4	10.9	13.3	16.1	18.1	[2]19.6	....	....	....	....
Spotted bass	68	5.2	10.2	12.4	13.6	14.5	[2]14.3	....	....	....	....
White bass	58	7.3	11.9	13.3	14.1	....	....	....	....	....	....
Bluegill	97	1.7	3.0	4.4	5.6	[2]6.8	....	....	....	....	....
Freshwater drum	161	4.5	9.1	11.3	12.5	14.2	....	....	....	....	....
Carp	128	6.6	9.5	13.5	15.3	19.2	....	....	....	....	....
Gizzard shad	114	4.1	6.8	8.3	9.2	9.8	10.3	10.9	11.7	12.0	11.7

[1] Computations were based on the following body-scale (L/S) relationships: white crappie—curvilinear relationship described by equation $L=30.093+1.604S-0.00489S^2+0.0000122S^3$ (Witt, 1952); largemouth bass and white bass—assumed linear relationship with an estimated intercept of 1 inch on the L-axis; spotted bass—assumed linear relationship with an estimated intercept of 0.4 inch; bluegill—assumed linear relationship with an estimated intercept of 0.8 inch; freshwater drum—linear relationship expressed by equation $L=0.12+1.25S$; carp—linear relationship described by equation $L-0.2+2.2S$; gizzard shad —assumed linear relationship with an estimated intercept of 0.7 inch.

[2] One fish

average for reservoirs in Missouri except for bluegill and gizzard shad.

Bluegill grow slowly in this lake. Their average length, after 3 summers of growth, is 4.4 inches and it appears that most of them require 4 growing seasons to attain a length of 5.5 inches. Presumably the lack of vegetation, unstable water levels, and competition for food curtail the insect and plant food supply upon which the bluegill depends.

Although first-year growth of gizzard shad in Lake Wappapello is fairly rapid, the increment is small in succeeding years of life. The gizzard shad population was dominated by old fish, particularly the 1943 year class. This year class comprised 58 percent of the total catch in 1949, and it was numerically dominant in the collections of scale samples taken at random in 1950 and 1951. Ten-year-old gizzard shad were taken in the gill nets in 1951, indicating that shad have survived for 10 years following the first hatch in the impoundment. Gizzard shad less than 6 years old comprised only 20 percent of the entire collection.

A long life span usually is not associated with this species. Lagler and Applegate (1942) found no gizzard shad more than 5 years old in two

Indiana ponds. Thompson (1950) presented growth data for this fish in Grand Lake, Oklahoma, not one of which was over 5 years old. Most of the gizzard shad collected in other Missouri reservoirs are no older than 5 or 6 years.

The growth rate of carp was determined from scale samples taken in 1949 and 1950. The 1946 year class was well represented in the net catches of 1949, 1950, and 1951. Sixty-six percent of the 1949 catch were 3 years old, and an estimated 50 percent of the carp collected in 1950 were 4 years old. Few scale samples were taken in 1951 and the evidence of year-class strength is not as clear. However, carp 18–21 inches long (presumed to be 5-year-old fish) comprised 34 percent of 135 carp taken in 1951. Only 9 percent of the carp in the net catches of 1950 and 16 percent of those caught in 1949 were in this length range.

Growth data on the largemouth bass and spotted bass are limited. Most of the material was supplied by anglers in 1951. The rates of growth of these species compare favorably with the growth rates in other Missouri reservoirs. Largemouth bass grow faster than spotted bass in this lake. Age-group III (1948 year class) provided the bulk of the harvest of both species in 1951. Forty-eight percent of the largemouth bass and 60 percent of the spotted bass in the creel census were 3-year-old fish.

The rate of growth of white crappie in Lake Wappapello is slightly under the average for the species in Missouri impoundments (Witt, 1952).[3] However, crappie attain a total length of 10.2 inches by the end of the third year of life. The white crappie population sampled by the hoop nets in 1948 contained a much higher percentage of 3- and 4-year-old fish than did the populations sampled in succeeding years with these nets (Table 6). Two-year-old crappie dominated the catch in 1949, and there

TABLE 6.—*The percentage of white crappie of the various year classes in the hoop-net catches from Lake Wappapello*

Year class	Percentage of catch in year of collection			
	1948	1949	1950	1951
1943	2.3	....	....	....
1944	17.0	....	....	....
1945	22.5	1.7	0.6	....
1946	44.2	3.4	0.6	1.2
1947	13.9	68.9	6.5	0.6
1948	....	25.8	33.3	7.6
1949	....	....	58.9	48.8
1950	....	....	....	41.8
Number of fish	129	58	168	170

was a pronounced increase of 1-year-old fish in 1950. The 1949 hatch provided the bulk of the increase in hoop-net catches in 1950 (Table 2). Ninety percent of the 1951 hoop-net catch of white crappie were 1- and 2-year-old fish.

[3] Age and growth of the white crappie, *Pomoxis annularis*, Rafinesque, in Missouri. Ph.D. thesis submitted to University of Missouri in 1952 by Arthur M. Witt.

Creel Census

From 1946 to 1950 the lake was included in a state-wide, continuing creel-census program. During that period, 10,854 fishermen were interviewed by Conservation Commission employees. These fishermen creeled fish at an average rate of 0.45 fish per hour, and 71 percent of the anglers were successful in taking fish.

In each of the 5 years, boat fishermen made up more than 80 percent of the anglers, and fishermen who "still" fished also comprised over 80 percent. The anglers who used live baits constituted at least 95 percent of the fishermen.

An intensive creel census similar to that described for Clearwater Lake, Missouri by Kathrein (1951) [4] was begun in May 1951. Of the 5,367 fishermen contacted by the clerk, 66 percent succeeded in creeling at least 1 fish. Their rate of catch was 0.53 fish per hour. Ninety-one percent fished from boats and 75 percent used natural baits exclusively. Only 1 percent of the fishing was done with artificial lures.

The species composition of the catch in 1946–1950 and that of the intensive census of 1951 is shown in Table 7. Crappie strongly dominated the fishery. They made up more than 80 percent of the catch each year.

Table 7.—*Species composition of the catch from Lake Wappapello as measured by the state-wide creel census, 1946-1950, and the intensive creel census in 1951*
[Numbers are percentages of the total number reported in the creel census for each year]

Species[1]	1946	1947	1948	1949	1950	1951
Crappie[2]	82.5	90.3	86.9	83.1	82.3	88.1
Carp	0.9	1.1	1.2	4.4	5.4	2.7
Largemouth bass[3]	9.6	6.4	6.3	4.3	4.2	1.4
White bass	1.3	[4]...	[4]...	1.1	1.9	1.4
Channel catfish	[4]...	[4]...	[4]...	[4]...	1.6	3.3
Bluegill	3.5	[4]...	1.9	4.9	2.4	[4]...
Green sunfish	[4]...	[4]...	1.1	[4]...	[4]...	[4]...
Total number of fish	2,475	8,137	8,465	4,729	1,847	16,869

[1] Other species in the creel census that comprised less than 1 percent of the catch include freshwater drum, flathead catfish, buffalo, bowfin, warmouth, yellow walleye (*Stizostedion v. vitreum*), smallmouth bass (*Micropterus dolomieui*) and bullheads (*Ameiurus* spp.)
[2] Mostly white crappie
[3] Includes spotted bass
[4] Less than 1 percent

No attempt was made by the census takers to distinguish between white and black crappie, but it is believed that the creel was almost entirely white crappie (Table 1). The dominance of crappie in the creel resulted from still fishing with minnows, the principal method of angling on the lake. This method is a successful and popular means of catching crappie in Missouri reservoirs.

From 1946 to 1950 black bass showed a steady decline as measured by creel returns obtained by the state-wide creel census. Furthermore, in

[4] A preliminary report of an intensive creel census conducted at Clearwater Lake, Missouri in 1949 and 1950. Presented at the 13th Midwest Wildlife Conference by Joseph W. Kathrein.

the intensive census of 1951, these fish comprised only 1.4 percent of the catch. However, the intensive creel census shows that few anglers fish for black bass.

White bass have not become important in the creel. Relatively few carp and buffalo have ever been recorded in the catch, and freshwater drum have never comprised as much as 1 percent of the take.

Few fishermen fish with trotlines. Only 4 percent of the fishermen used this method in 1951. Nevertheless, they took 90 percent of the carp harvested, 42 percent of the channel catfish, and 85 percent of the flathead catfish. Freshwater drum, buffalo, and bowfin also were taken on trotlines. Fifty-two percent of the trotline catch consisted of species classified as non-game fish by the Missouri Conservation Commission.

The intensive creel census of 1951 provided data from which reasonably accurate estimates of fishing pressure and yield were computed. An average of 34 fishermen were on the lake between one half hour after sunrise and one-half hour after sunset. They averaged 5.9 hours of fishing per trip and 3.1 fish per man. It was estimated that fishing pressure was applied to Lake Wappapello in 1951 at the rate of 21.2 hours, or 3.6 fisherman-days per acre. This rate is low. Fish were removed at the rate of 11 fish, or about 6.3 pounds per acre.

The low estimate of yield from Lake Wappapello in 1951 resulted not only from low fishing pressure but also from the omission of early-spring fishing from the census. Early-spring fishing is usually very good on Missouri reservoirs. Inasmuch as the census was not started until May 8, an estimated 6 weeks of good fishing were missed. Another factor responsible for the low yield is the small size of the fish. White crappie that averaged an estimated 7 ounces in weight dominated the creel.

In 1951 it was estimated that 50,575 fish were harvested from the reservoir between May 8 and December 31. Of this total, 44,575 were crappie, 1,675 were channel catfish, and 1,375 were carp. An estimated 700 black bass and as many white bass also were creeled in 1951.

Appraisal of the Fishery and Recommendations

The investigation of the fishery in Lake Wappapello was prompted by the decline in black bass fishing. The evidence acquired by seining and rotenone treatment, when compared with similar censuses in other large Missouri impoundments, suggests a good population of largemouth bass which is not being utilized. In 1951, adult largemouth bass were recovered in greater numbers in Lake Wappapello than in four other Missouri impoundments censused in a similar manner. Futhermore, reproduction in 1949, 1950, and 1951 is believed to have been satisfactory. Few anglers fish for bass in the lake. This fact accounts for the low standing of black bass in the creel.

Spotted bass appear to be outnumbered by the largemouth bass at the present time, although the former is believed to have been the dominant black bass in the St. Francis River before the construction of the reservoir.

However, a seining survey of backwaters in 1941 produced evidence of a successful spawn of the largemouth bass in the first year of impoundment.

Although the creel is large, there is no evidence that the white crappie is on the decline. Old crappie were prevalent in 1948 but young fish were abundant in the hoop-net catches of 1950 and 1951. An excellent spawning was observed in 1951. Over the 4-year period, 42 percent of the crappie captured in all of the nets were 10 inches long or longer. It is believed that the species can withstand a greater harvest without harm to the population. Good reproduction, an adequate rate of growth, and relatively light fishing pressure on the lake suggest that the daily limit of 12 could be increased.

Black crappie have failed to become well established in this reservoir despite a stocking of 10,000 in 1941. An estimated 70 percent of these fish were of legal size when they were stocked. Judging from the ratio of white to black crappie revealed by the netting (Table 1), the stocking was unsuccessful.

White bass inhabited the St. Francis River before impoundment, but they have not become important in the creel. This species, too, has been stocked in the reservoir. Bluegill provide a small part of the hook-and-line harvest. Their growth rate is slow, and it is doubtful whether they will become important in the catch.

There is an abundance of non-game fish in this 10-year-old impoundment. These fishes made up 70 percent, by weight, of the total net catch. Carp accounted for 49 percent by weight of the combined net catches each year. A similar preponderance of non-game fish was found in the backwater areas where 65 percent of the standing crop, by weight, was composed of large non-game species. Buffalos were abundant in these waters.

Inasmuch as few non-game fish are harvested even though they are abundant, it has been recommended that a commercial fishery be considered for Lake Wappapello.[5] Many non-game fish which should be harvested are never utilized. Recommendations also have been made to permit year-round gigging (spearing) for non-game fish in the reservoir to encourage a greater yield of these food fishes. Spring gigging for carp during their spawning period could add considerably to the harvest. At present, Missouri regulations permit gigging from October 1 to December 31, between the hours of noon and midnight.

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[5] At present, this is contrary to the Missouri Conservation Commission's policy for impounded waters.

general information concerning the reservoir and its watershed. Data on the creel censuses were obtained from Mr. John L. Funk and Mr. Joseph W. Kathrein. Special credit is due Mr. Howard Watson for his aid during the 4 years of field work, and to Mr. James L. Warner who collected creel-census data between 1947 and 1950.

Literature Cited

American Fisheries Society
1948. A list of common and scientific names of the better known fishes of the United States and Canada. Am. Fish. Soc., Special Pub. No. 1, 45 pp.

Ball, Robert C.
1947. A tagging experiment on the fish population of Third Sister Lake, Michigan. Trans. Am. Fish. Soc., Vol 74 (1944), pp. 360–369.
1948. Recovery of marked fish following a second poisoning of the population in Ford Lake, Michigan. Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 36–42.

Brown, C. J. D., and Robert C. Ball
1943. A fish populaton study of Thrd Sister Lake. Trans. Am. Fish. Soc., Vol. 72 (1942), pp. 177–186.

Crowe, Walter R.
1950. Construction and use of small trap nets. Prog. Fish-Cult., Vol 12, pp. 185–192.

Krumholz, Louis A.
1950. Some practical considerations in the use of rotenone in fisheries research. Jour. Wildlife Man., Vol. 14, pp. 413–424.

Lagler, Karl F., and Vernon C. Applegate
1942. Age and growth of the gizzard shad, *Dorosoma cepedianum* (Le Sueur), with a discussion of its value as a buffer and as forage of game fishes. Invest. Ind. Lakes and Streams, Vol. 2, No. 6, pp. 99–110.

Moyle, John B., Jerome H. Kuehn, and Charles R. Burrows
1950. Fish—population and catch data from Minnesota Lakes. Trans. Am. Fish. Soc., Vol. 78 (1948), pp. 163–175.

Tarzwell, Clarence M.
1942. Fish populations in the backwaters of Wheeler Reservoir and suggestions for their management. Trans. Am. Fish. Soc., Vol. 71 (1941), pp. 201–214.

Thompson, Bill
1950. Investigation of the fisheries resources of Grand Lake. Okla. Game and Fish Dept., Fish. Man. Rep. No. 18, 46 pp. (mimeographed).

Trautman, Milton B., and Robert G. Martin
1951. *Moxostoma aureolum pisolabrum*, a new subspecies of sucker from the Ozarkian streams of the Mississippi River system. Occ. Pap. Mus. Zool., Univ. Mich., No. 534, pp. 1–10.

GROWTH RATES OF BLACK BASSES AND CRAPPIE IN AN IMPOUNDMENT OF NORTHWESTERN LOUISIANA

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ABSTRACT

Rapid growth of several species of fishes, including the largemouth and spotted basses (*Micropterus salmoides* and *M. punctulatus*) and the black crappie (*Pomoxis nigromaculatus*), was observed during 3 successive summers, 1949–1951, in a reservoir at Springhill, Louisiana. The basin is filled in April and drained in September or October. Largemouth bass young of the year grew to sizes ranging up to 13.8 inches and up to 24.5 ounces during the retention period. The greatest growth in weight for this species was 3.8 ounces per month during a 6½-month period in 1950. The highest average was 3 ounces per month during a 5½-month period in 1949. The average accretion in weight for the spotted bass was less than half that of the largemouth bass. Black crappie grew up to 9.8 inches and 12 ounces during a 6½-month retention period. Summaries of life-history data are included in a table.

During the summers of 1949, 1950, and 1951, rapid growth of several species of fishes was observed in a reservoir of the International Paper Company at Springhill, Louisiana. The effective surface area of the artificial basin is about 270 acres; its capacity is about 185 million cubic feet and its maximum depth about 28 feet, of which 24 can be drained by gravity. Pumps with an aggregate capacity of some 22,000 gallons per minute, enough to fill the basin in 40 days, lift the water from adjacent Bodcau Bayou.

The basin is filled during April and May, at which time large numbers of newly hatched fry could be expected to be present in the bayou. These fry, as well as older age groups of small species, would not be able to fight the current created by the huge pumps. Larger fish, however would be checked by the ½-inch screens through which the water is strained.

When the pond is first flooded, schools of unguarded small fish can be seen along the shores. Young largemouth bass, spotted bass, black crappie, black bullheads, carp, and sunfishes take baited hooks readily by the middle of July. The two black basses can be taken also on artificial baits. By late summer, anglers have a "field day" almost every day. The water in the reservoir, with its incidental crop of fish, is drained into Bodcau Bayou during September or October to make room for waste water from the paper mill.

This waste water is a dilute effluent from the sulphate process, known

to the industry as "blackwater." It has a high oxygen demand and its dissolved-oxygen content is usually nil. This water is held in the basin for some 5 months or more, usually from October or November through March, and is judiciously discharged into the bayou during this period. The rate of discharge is governed by temperature, turbulence, and dilution factors in the stream, as shown by routine hydrographic and chemical checks.

By the end of March, when the blackwater level in the basin is reduced to the level of the bayou, there are some pools and pits which cannot be drained. This residual blackwater may mingle with bayou water for some few days at least. During 1949 and 1950, coincident with rising water levels in the bayou, some fish of various species and ages entered through the outlet before it was closed. The most abundant of these was the adult gizzard shad, which seems to move in large schools. During April 1951, there was only a slight rise on the bayou at the time of closing the outlet, and it is doubted if any fish entered the residual pits which then contained practically undiluted blackwater. In view of the conditions, there can be little doubt that virtually all young of early-spawning species found in the basin develop from fry which have been drawn through the screens.

Incidental observations were made throughout the summer, but the main studies were made at the end of each season. Fish were taken with seines, traps, baited hooks, artificial baits, and on the outlet screens. After draining, thousands of specimens were collected in the residual pools and pits. Random samples were taken for study.

Of some 30 species of fishes found in the basin, the following could be considered more or less abundant: gizzard shad (*Dorosoma cepedianum*), spotted sucker (*Minytrema melanops*), golden shiner (*Notemigonus crysoleucas*), silvery minnow (*Hybognathus nuchalis*), carp (*Cyprinus carpio*), southern black bullhead (*Ameiurus melas catulus*), gambusia (*Gambusia affinis*), pirate-perch (*Aphredoderus sayanus*), logperch (*Percina caprodes*), spotted bass (*Micropterus punctulatus*), largemouth bass (*Micropterus salmoides*), green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), black crappie (*Pomoxis nigromaculatus*).

The number of species as well as their relative abundance varied from year to year. The life-history data for the 3 major predatory species are summarized in Table 1. Scale readings and stomach examinations were made of all specimens in the random samples as well as of many others. Young fish taken for study in September 1949 were considered to be about 5½ months old, whereas the October crops of 1950 and 1951 were about 6½ months old. In order of abundance, the black crappie led these three species in 1949 and 1950, followed by the spotted bass and then the largemouth bass. In 1951, however, the largemouth bass population rose to dominance, followed by the spotted bass, and a relatively small crappie population.

Each year the three major predatory species showed the following diminishing order of average lengths and weights: largemouth bass, spotted

TABLE 1.—*Summarized life-history data for the three major predatory species in Springhill Basin*

Species	Year	Date	Retention period (months)	Number of fish	Total length (inches)		Weight (ounces)		Mean monthly growth (ounces)		Condition factor[1]	
					Mean	Range	Mean	Range	Mean	Range	Mean	Range
Largemouth bass	1949	Sept. 23-24	5.5	21	11.8	11.1-12.4	16.5	12.9-19.5	3.0	2.3-3.5	63	57-75
	1950	Oct. 28-29	6.5	34	12.5	11.1-13.8	18.0	11.4-24.5	2.8	1.8-3.8	57	48-66
	1951	July 16-17	3.5	18	6.7	5.3- 8.0	3.0	1.3- 5.2	0.9	0.4-1.5	56	46-65
		Aug. 23	4.5	29	8.8	4.9- 9.9	6.8	0.9-10.0	1.5	0.2-2.2	59	42-73
		Oct. 18-20	6.5	39	10.6	6.3-13.5	10.3	2.3-20.0	1.6	0.4-3.1	49	40-59
Spotted bass	1949	Sept. 22-24	5.5	42	9.1	5.4-10.2	7.3	1.0-11.1	1.3	0.2-2.0	57	38-67
	1950	Oct. 25-29	6.5	42	9.5	6.1-10.6	7.1	1.4-11.6	1.1	0.2-1.8	49	28-61
	1951	July 17	3.5	2	6.1	5.8- 6.4	2.5	2.1- 2.8	0.7	0.6-0.8	65	64-66
		Aug. 23	4.5	6	7.3	6.7- 8.0	3.3	2.5- 4.7	0.7	0.6-1.0	53	50-57
		Oct. 20	6.5	6	8.9	7.5- 9.7	5.7	2.6- 7.3	0.9	0.4-1.1	47	35-50
Black crappie	1949	Sept. 22-24	5.5	19	5.6	5.0- 9.4	1.7	1.0- 9.2	0.3	0.2-1.7	48	42-69
	1950	Oct. 19-25	6.5	33	7.4	5.8- 9.8	3.9	1.4-12.0	0.6	0.2-1.8	54	42-85
	1951	Oct. 20	6.5	5	8.1	7.0- 8.9	5.6	3.9- 7.9	0.9	0.6-1.2	64	58-70

[1] Determined from alinement charts A and B, Carlander (1950)

bass, black crappie. These averages reflect a combination of hereditary and environmental influences on the rates of growth of the populations as a whole during their first few months of life. The maximum figures, however, tend to reflect the inherent growth limitations in the presence of abundant food. It is surprising, in this connection, that the maximum weights attained by the black crappie in 1950 and 1951 were slightly in excess of those for the spotted bass.

Supporting the predatory population were large numbers of small carp, gizzard shad, sunfishes, golden shiners, silvery minnows, and other species. Midge larvae and plankton crustaceans supported the small game and pan fishes, carp, catfishes, and minnows. The stomachs of black crappie up to the largest sizes in the basin were frequently packed with midge larvae. The gizzard shad fed on both phyto- and zooplankton of small sizes. Summarized notes for each year of the study are given below.

Fish Population and Growth in 1949

When the basin was drained in September 1949, the numerical order of preponderant species was: bluegill, carp, black crappie. The spotted bass, black bullhead, green sunfish, spotted sucker, gizzard shad, pirate-perch and minnows were numerous. The largemouth bass was a noticeable but relatively small numerical constituent of the 1949 population.

The basses and crappie taken in the random samples were all young of the year. Scale readings showed that growth was remarkably uniform from time of hatching. After the study was completed, a single second-summer largemouth bass was found in one of the pits along with several 7-pound carp.

The largemouth bass showed the fastest growth of any species. Specimens ranged from 11.1 to 12.4 inches and from 12.9 to 19.5 ounces. The average for the series was 11.8 inches and 16.5 ounces. The maximum increment per month was 3.5 ounces and the average 3 ounces.

Spotted bass outnumbered the largemouth bass by at least 20 to 1. Their variation in size was much greater than the largemouth bass—5.4 to 10.2 inches and from 1.0 to 11.1 ounces. The maximum monthly increment for the spotted bass was 2 ounces; the average was 1.3 ounces, less than half the rate of the largemouth bass.

Black crappie between 5 and 5.5 inches, weighing between 1 and 1.3 ounces, were present in tremendous quantities. About 10 percent of the population was in a larger size class, some of these attaining lengths over 9 inches and weights above 9 ounces. None showed annuli on their scales and growth was remarkably uniform. The maximum monthly increment for the black crappie was 1.7 ounces, but the average was less than 0.3 ounce.

There was no evidence, from stomachs examined, of predation between different size groups of the 3 principal species. Other predators, such as spotted gar, bowfin, and chain and grass pickerels, were present in insignificant numbers. Young carp were the predominant food form in the

stomachs of the basses. The general run of carp was small, 3 to 4 inches, total length. These fish were no doubt stunted because of the tremendous population of the species. Some individuals, however, were over 10 inches long and over 8 ounces in weight with a maximum of 11.2 inches and 11.6 ounces, a monthly increment of 2.1 ounces.

Fish Population and Growth in 1950

Catches of pan-sized crappie were more in evidence in the creels of anglers fishing in the basin in 1950 than in 1949. Largemouth bass were also taken in larger numbers.

The basin was drained a little over a month later than in 1949. At this time, the numbers of forage fishes seemed to be appreciably less than in September of the preceding year, but the individuals were generally of larger size. Most noticeable was a reduction of the carp population. Increases were evident in the black bullhead and largemouth bass populations.

As during 1949, fastest growth was made by the largemouth bass. The variation in size was greater, however; lengths ranged from 11.1 to 13.8 inches and weights from 11.4 to 24.5 ounces. The averages were 12.5 inches and 18.0 ounces. The mean index of condition, 57, was less than in 1949 (63). The maximum increment for the largemouth bass, 3.8 ounces per month, was greater than during the preceding year, but the average dropped from 3.0 to 2.8 ounces per month.

The spotted bass outnumbered the largemouth bass by about 10 to 1. Again they grew at less than half the rate of the largemouth. Sizes ranged from 6.1 to 10.6 inches and from 1.4 to 11.6 ounces. There was only a slight increase in the average length for this species (9.5 inches) in spite of the longer retention period. The greater proportion of small individuals, with lower condition indices, brought the average weight (7.1 ounces) below that of the preceding year. The maximum increment per month for the spotted bass in 1950 was 1.8 ounces and the average 1.1—both figures less than in the preceding year.

The crappie decreased in numbers about 50 percent, but they doubled their rate of growth and their condition improved. In 1950, the largest black crappie was 9.8 inches and weighed 12 ounces, a handsome panfish for a 6.5-month-old specimen. The growth of this crappie averaged 1.8 ounces per month of its existence. This seems to be a record growth for this species (Carlander, 1950, p. 203).

Fish Population and Growth in 1951

As in 1950, the basin was drained in the latter part of October. The previous winter had been extremely severe, which no doubt meant a late spawning season on Bodcau Bayou and a different assortment of fry in the stream. The most significant population differences were greatly increased numbers of young largemouth bass and gizzard shad, and de-

creases in spotted bass and crappie as compared to 1950. Carp and black bullheads were about the same as in 1950. Therefore, carp were fewer but bullheads more plentiful than in 1949.

The variation in size of the largemouth bass was 6.3 to 13.5 inches, much greater than in either of the preceding two years. This situation could be expected in a much larger population. The mean of 10.6 inches was below that of the shorter 1949 retention period. Weights ranged from 2.3 to 20.0 ounces, with a mean of 10.3 ounces.

The condition index of the largemouth bass reached its peak (mean 59) during August. At that time they were feeding voraciously on young gizzard shad. By October, when the supply of young shad was all but exhausted, the condition index of this species (mean 49) reached its lowest figure during the 3-year study. Statistical studies and scale readings made in July and August 1951, as well as in October, dispelled any doubt as to the year class of these fish.

Spotted bass, judging from occasional observations and the small sample available, reached their peak of condition (mean 65) during July, a month earlier than the largemouth. At the end of the season, they too showed a lower condition index (mean 47) than in either of the previous 2 years.

The black crappie population, an insignificant component of the 1951 fish crop, was of larger average size and in much better condition (mean 64) at the end of the season than during the previous years.

Interpretation of Factors Affecting Population Dynamics in Springhill Basin

Sunlight penetration in blackwater is only about 2 inches. This alone would preclude the development of submerged aquatic plants in the Springhill basin during blackwater-storage periods. Thus there is no storage of nutrient salts within bulky plant tissues from which recycling is a slow process. On the contrary, the prevailing anaerobic conditions activate the mineralization of any organic matter, except the protoplasm of living anaerobic organisms, which happens to be in the blackwater from one source or another.

Some of the mineralized material remains in the residual pits and surface layer of mud when the blackwater is drained off during the winter months. The nutrients contained therein are available for immediate reuse as soon as the oxygen-saturated water from the stream is pumped into the basin. Aerobic bacteria and green and bluegreen phytoplankton develop rapidly and form the basic food supplies for protozoans, rotifers, entomostracans, midges, and other minute animals.

Thus the basic production factors during the alternate periods of freshwater impoundment in the Springhill Basin are essentially similar to those found in almost any newly impounded water in the deep South. The fry of some 30 species of fishes pumped through the screens have abundant food and a choice according their preferences. They can make suitable

adjustments as their food habits change variously with growth. Predators can shift early in life to a fish diet which is ample for their needs, and phenomenal growth rates are the result.

Thus, not only is there no evidence that the periodic storage of blackwater has any unfavorable effect on the fish life which develops during the alternate periods of freshwater impoundment, but, on the contrary, the periodic recycling of nutrients rejuvenates the basin annually. The food chains are shortened, the pond metabolism is accelerated, the fish become an annual crop, and senescence of the impoundment is prevented. The ecological factors, therefore, are much more favorable for the rapid production of desirable fishes than those existing in natural waters, or those which develop in most unmanaged impoundments after a few years.

I have eaten many of these fish and can rate their quality superior to most wild fish, equal to the quality of the same species reared in suitably fertilized impoundments. None of them have the "muddy" or "grassy" flavors of fish from senescent ponds choked with aquatic weed beds.

The original assortments of species found in the basin are undoubtedly determined accidentally by the initial stocking with fry drawn through the pumps from Bodcau Bayou. Variations in these initial stocks from year to year would be determined by water temperatures and stages existing in the bayou at the time. Spawning dates would certainly be influenced materially, as well as the movements of small fish along the banks where they would come under the influence of the pumps. The almost complete absence of black crappie in the basin after the severe winter of 1951 would seem to indicate a delay in the spawning season or an almost complete loss of that year class as a result of the cold. The excessive carp population in 1949 as compared to subsequent years would indicate an unusually favorable spawning season for the species during that year.

Subsequent adjustments in relative abundance and changes in condition factors of species or size classes during the retention periods undoubtedly result from the dynamics of predator-prey-forage relationships. The reduced condition factors of the black basses after longer retention periods, simultaneous with the progressive numerical reduction of young carp and gizzard shad, while the remnants of these latter populations grew too large for bass to devour, are offered as evidence in this respect.

Field observations and analysis of the data indicate that both intraspecific and interspecific competition are involved. The largmouth bass and the black crappie were in best condition when their respective populations were at a minimum—the former in 1949, the latter in 1951. In this deep basin, these 2 species are not in serious competition. Their food selection is from a different size range, and angling returns showed that the largemouth bass foraged principally in the upper 10 feet of water, whereas the crappie foraged mostly in the lower 10 feet. It is obvious then that intraspecific competition played the greater role in regulating the quality of these populations under the conditions existing.

The situation was somewhat different with the spotted bass, a species

characteristic of stumpy, spring-fed streams (Viosca, 1933), which is out of its favored habitat in open water. In the Springhill Basin, this species was taken generally deeper than the largemouth bass but not as deep as the black crappie. At times it is compelled to share its food with either one or both of the other species in an interspecific competition.

Although their numerical population was greatest in 1949, the spotted bass were in best condition and made fastest growth during that year. This situation was obviously due to the tremendous numbers of small carp in the basin at the time. Crowding stunted these carp and held them down to a suitable size for the spotted bass. There were relatively few largemouth bass in the basin in 1949 so competition from that species was of little significance. The small carp, however, were too large for the crappie. Therefore, interspecific competition did not affect the population of the spotted bass that year and their condition factor remained at a high level until the pond was drained.

During 1950, with carp relatively scarce and both largemouth bass and black crappie plentiful, interspecific competition seriously affected the spotted bass. The faster growing largemouth bass, with their much larger mouths, had a decided advantage when young gizzard shad were feeding at the surface in schools. At lower levels spotted bass were in competition with the black crappie. Pressure from the crappie came about in two ways—by the removal of great quantities of midge larvae by the crappie to the detriment of the minnow population in the lower zones, and by the removal of quantities of the smaller minnows by the crappie.

Crappie were scarce in 1951 and did not seriously compete with the spotted bass that year. As a consequence, the young spotted bass were in prime condition in July of that year when an abundant supply of small fish was available to them. As these forage fish grew and became more attractive to the then abundant largemouth bass, coincident with a reduction of the surface-feeding gizzard shad, the largemouth bass were forced to feed at lower levels. Both black basses were then in serious competition, and the condition factors of both declined as the season advanced.

The relative desirability of food forms must be considered in terms of size, shape, and chemical sense appeal. Record growths of the two bass species were made in 1949 when unlimited numbers of small carp were available. Judging by the numbers found in the stomachs of the basses, the flavor appeal of carp must be high. Because of their shape and size, much more bulk per feeding effort could be obtained from the carp than from either the shad or the sunfishes. Although sunfishes were always present in the basin in greater numbers than either carp or gizzard shad, very few sunfishes were found in the stomachs of either of the black basses. Gizzard shad, minnows, and carp, all species with high flavor appeal, were decimated toward the ends of the longer retention periods in 1950 and 1951; yet the black basses did not take advantage of the vast sunfish populations still available. This fact is significant because sunfishes, especially

bluegills, are almost universally recommended as forage fish for farm ponds throughout the South.

The crappie-carp relationship presents a very different picture from the bass-carp relationship. Young carp are too large for crappie of the same age-group to consume. As midge larvae are the prevalent food for both carp and crappie in the Springhill Basin, these two species are in direct interspecific competition. The abundance of both carp and crappie in 1949 undoubtedly resulted in the stunting of both species, except that a small number of fish-eaters developed among the crappie, producing two distinct size groups of the same age class. A sample of the smaller size class, the midge-eaters, averaged 1.2 ounces and had a mean condition factor of 46, whereas the larger but less numerous size class, the fish-eaters, averaged 6.9 ounces and had a mean condition factor of 64.

A reduced carp population would tend to bring about an increased midge population and thus contribute to the benefit of the crappie both through the greater availability of midges for direct consumption by the crappie and through an increased population of small midge-eating minnows, such as the silvery minnow, which are also part of the crappie diet.

Compared with growth rates for the same species given by Carlander (1950), it seems that the growth rates recorded in Table 1, especially the maxima, are records for these species for unfertilized waters in their first few months of life. In the largemouth bass, for which we have other Louisiana records for comparison (Table 2), they equal or better the rates for the same age classes in fertilized waters.

In the practical application of such data, the fish grower is warned not to be misled by an increase in maximum values during a longer retention

TABLE 2.—*Rate of growth in ounces per month for largemouth bass in Louisiana, from various records (Viosca 1943) and for the Springhill Basin*
[Initial age of 0 indicates local reproduction or introduction as fry]

Location	Condition	Year	Initial age (months)	Retention period (months)	Growth	
					Mean	Maximum
Beechwood Hatchery	Not fertilized	1925	0	6½	[1]1.3	1.8
Beechwood Hatchery	Not fertilized	1925	0	7	...	2.3
Concordia Hatchery	Not fertilized	1928	0	9	[1]2.2	...
Beechwood Hatchery	Fertilized	1941	0	7	[1]4.3	5.0
Beechwood Hatchery	Fertilized	1941	4	4	...	7.0
Beechwood Hatchery	Fertilized	1941	16	7	[1]5.4	8.0
Lacombe Hatchery	Fertilized	1941	0	5	...	3.2
Lacombe Hatchery	Fertilized	1941	0	8	...	4.0
Lacombe Hatchery	Fertilized	1941	0	11	...	3.2
Lower Mississippi Valley	Flooded by river	1927	0	5	[1]3.0	...
Near New Orleans	New borrow pit	1942	0	34	...	2.5
Springhill Basin	Stream water	1949	0	5½	3.0	3.5
Springhill Basin	Stream water	1950	0	6½	2.8	3.8
Springhill Basin	Stream water	1951	0	3½	0.9	1.5
Springhill Basin	Stream water	1951	0	4½	1.5	2.2
Springhill Basin	Stream water	1951	0	6½	1.6	3.1

[1]Selected sample

period but rather to consider the average values for the population as a whole. In these predatory species, interspecific and intraspecific competition, interspecific predation, and cannibalism may all come into play. Even when productivity is poor, there are usually a few giants in the population.

To achieve maximum productivity, fairly uniform size, and an early harvest of these predatory fishes by controlled pond culture, a maximum rate of consumption of the forage fishes must be effected. A permanently balanced "favorable" ratio between forage fishes and predators is not conducive to these ends.

Judging from the results attained in the Springhill Basin, ponds initially unbalanced in favor of the forage fishes show promise of success. The ideal, of course, would be to rear the forage fishes in a succession of suitable sizes. They should also be of suitable shapes for producing the greatest possible food bulk with the least amount of feeding effort on the part of the predators. All should have high flavor appeal.

When the forage fishes have been reduced to such a level that the calories expended by the predators in gathering them, together with the requirements of basal metabolism, are greater than the calories provided by the diet, growth will cease and the condition factors will decline. A longer retention period will then mean decreased productivity. When the first signs of decimation of the forage crops appear, it is time for the harvest, or at least for partial removal, especially of the larger fish. We may be on the eve of producing predatory pond fishes economically as a harvestable crop.

Acknowledgments

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Literature Cited

Carlander, Kenneth D.
1950. Handbook of freshwater fishery biology. Wm. C. Brown Co., Dubuque, Iowa. 281 pp.

Viosca, Percy, Jr.
1932. The southern small-mouth black bass. Trans. Am. Fish. Soc. Vol. 62, pp. 95–98.
1943. Phenomenal growth rates of largemouth black bass in Louisiana waters. Trans. Am. Fish. Soc., Vol. 72 (1942), pp. 68–71.

RETURNS FROM PLANTINGS OF LEGAL-SIZED BROOK, BROWN AND RAINBOW TROUT IN THE PIGEON RIVER, OTSEGO COUNTY, MICHIGAN [1]

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ABSTRACT

A complete census of fishing on 4.8 miles of the Pigeon River, together with population estimates made at the end of the open season, made possible an accurate evaluation of the yield and survival of open-season plantings of hatchery trout. Fishing intensity in this research area for 3 years averaged 2,414 daily trips per year which was equivalent to 278 hours of fishing effort per acre per year. Sections in which hatchery fish were planted attracted about three times as much fishing as did the unplanted sections.

Fishing quality, measured by the catch per hour per fishing trip, was generally poor for native fish, averaging less than 1 fish for 5 hours of effort. Hatchery fish made up about 70 percent of the total catch for the 3 years.

Planting trout from a live-crate a few at a time (scatter-planting) did not prove to be advantageous over the practice of liberating large numbers of fish in one hole (spot-planting). Trout that had been scatter-planted did not contribute to the catch for a longer period of time, and produced fewer successful fishing trips, fewer total fish returned to anglers, and slightly fewer anglers sharing in the total catch. However, the practice of making several plantings on different dates, a few fish at a time, permitted more individual anglers to share in the catch.

Although 4,500 legal-sized trout were planted each year, about half of the fishing trips were unsuccessful. Limiting the daily catch to 5 trout, instead of 15, did very little to reduce the percentage of unsuccessful anglers. Further reduction to 2 fish per day lowered the unsuccessful fishing trips to 36 percent.

Plantings of rainbow trout and brook trout gave much higher returns to the fishermen than did equal numbers of brown trout. Rainbow trout also survived over winter as well as did brown trout, although in both species the survival was less than 10 percent. Over-winter survival of brook trout was less than 3 percent. Fin-clipped trout were recovered by fishermen more readily than those which were jaw-tagged. This difference was especially apparent during the first week following planting.

Rainbow trout and brook trout, planted when water temperatures were below 50°F., exhibited an immediate downstream movement. Fish planted when water temperatures were above 50°F. showed very little movement.

Legal-sized brook, brown, and rainbow trout, planted in a stream subjected to heavy fishing pressure, contributed to the catch for a relatively short time. Brook trout were exploited most readily; only 4 percent of the recoveries were taken after 40 days of liberty. For brown trout and rainbow trout these values were 26 percent and 22 percent, respectively.

Planting large numbers of hatchery fish (up to 431 trout per mile) apparently

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had no effect upon the catch of wild fish in the stream. Although the catch per hour of the planted trout increased greatly at the time of planting, the corresponding weekly data on catch-per-hour of the wild trout showed no similar increase.

Introduction

In April 1949, the Pigeon River Trout Research Area was established at the site of the State Forest Headquarters, 13 miles east of the town of Vanderbilt, Otsego County, Michigan. Here, a portion of the Pigeon River 4.8 miles long was set aside for studies of the life history and management of the three species of trout of importance in Michigan streams.

For the past several years, emphasis in stream management has been placed on the supplemental planting of legal-sized trout, just before and during the open season. The results of many experiments in Michigan and elsewhere with plantings of this kind have already been published. The present work is a continuation, in this state, of previous experiments (Hazzard and Shetter, 1939; Shetter and Hazzard, 1941; Shetter, 1947). In the present study, however, more accurate creel-census data were obtained through the compulsory permit system and good estimates of residual populations were made by electrofishing devices. Some of the conclusions reached in previous studies are untenable in the light of present knowledge, but in general agreement is good between the results of present studies and previous data published both from Michigan and from other states. A good review of previous investigations on results of planting legal-sized trout is given by Shetter (1947).

The 4.8 miles of stream under experimental control have been arbitrarily divided into four fishing sections of approximately equal length (Fig. 1). Weirs or other barriers to movement are not present within the research area. The lower section (A) supports a poor population of native trout compared to the stocks in the other sections, although the physical features of the stream sections, except for minor differences in temperatures, are closely similar (Table 1). Native brook trout outnumber brown trout in the stream about 3:1, and wild rainbow trout are encountered rarely.

Table 1.—*Morphometry of the experimental portion of the Pigeon River*

Physical feature	Section				Total or average
	A	B	C	D	
Length (miles)	1.31	1.19	1.13	1.18	4.81
Average width (feet)	45	41	40	40	41
Area (acres)	7.16	5.90	5.39	5.65	24.10
Gradient (feet per mile)	9.63	9.53	12.20	7.69	9.74

A permit-type of creel census was operated on the experimental waters during the 3 years. Each fisherman was required by Conservation Commission order to register at a checking station (headquarters) to obtain a

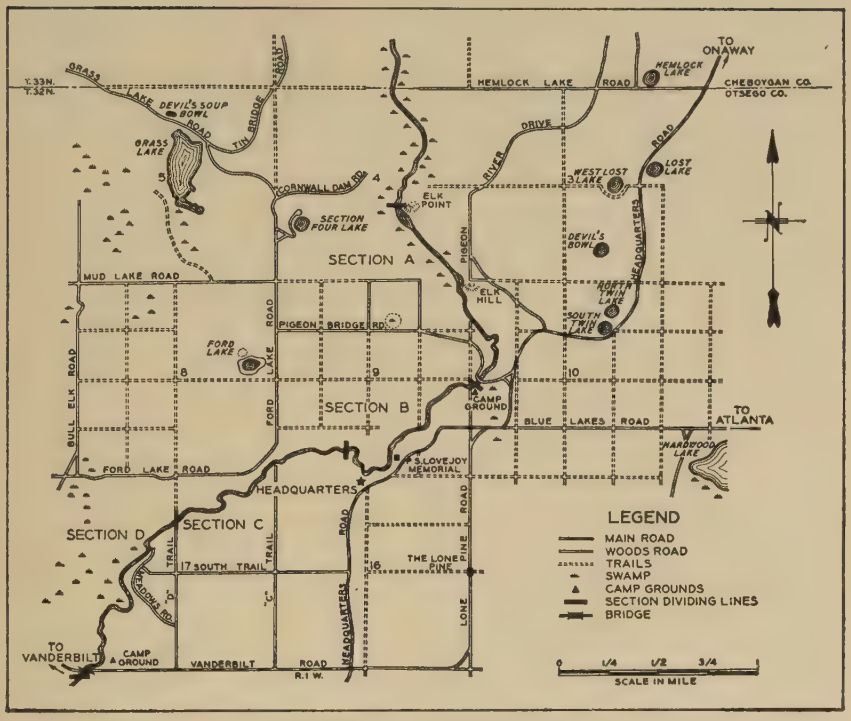

FIGURE 1.—Map of a section of the Pigeon River in Otsego County, Michigan, showing the four experimental sections (A to D) and location of the creel-census headquarters.

daily permit. At the close of fishing in a particular section of the stream, the angler was required to return his permit to the checking station and report his fishing success. The general willingness on the part of the public to submit to this program provided a nearly complete and a highly accurate record of the results of fishing. No charge was made for a permit and an angler could fish in as many sections of the stream as he wished by obtaining additional permits.

FISHING INTENSITY

Fishing intensity in the experimental waters for the 3 years averaged 2,414 daily trips per year (Table 2). This fishing was equivalent to 100 fishing trips or 278 hours per acre per year. The sections in which hatchery fish were planted (Sections B and C) attracted more fishermen (155 fishing trips per acre per year) than did the unplanted sections (52 per acre per year). The majority of the fishing was done on week ends and holidays; Saturdays and Sundays alone accounted for about half of the fishing. July and

August averaged fewer fishermen per day than did May, June, and September.

About 1,200 different individuals fished in the area during each of the 3 seasons. Of these individuals, two-thirds fished only once, about 95 percent fished less than 5 times and only about 2 percent fished 10 or more times during the season.

TABLE 2.—*Fishing intensity in 4.8 miles of the Pigeon River, seasons of 1949, 1950 and 1951*
[Hatchery trout were planted in Sections B and C]

Year	Item	Stream section				All sections
		A	D	B	C	
	Area (acres)	7.16	5.65	5.90	5.39	24.10
1949	Number of fishing trips	282	330	858	763	2,233
	Total hours	861	1,021	2,385	2,550	6,817
1950	Number of fishing trips	333	397	814	616	2,160
	Total hours	898	1,276.5	2,130.5	1,890	6,195
1951	Number of fishing trips	367	277	1,252	954	2,850
	Total hours	950.5	818.5	3,148	2,159	7,066
1949 to 1951 (inclusive)	Number of fishing trips	982	1,004	2,924	2,333	7,243
	Total hours	2,709.5	3,116	7,663.5	6,599	20,098
1949 to 1951 (inclusive)	Average trips per acre per year	51.7		155.2		100.2
	Average hours per acre per year	151.6		421.1		278.0

RESIDENCE OF ANGLERS

A tabulation of the residence of anglers who fished the Pigeon River during the 3 years revealed that, in general, areas of the state with high population density furnished large numbers of fishermen. The local county (Otsego) was well represented, but not counties immediately adjacent. Almost no fishermen were from the Upper Peninsula, but anglers came from nearly all (58 out of 68) of the counties from the Lower Peninsula.

Out-of-state anglers comprised about 10 percent of the total. Ohio predominated over all other states, followed by Indiana and Illinois. During the 3 years, fishermen were recorded from 23 different states and the Province of Manitoba.

INDICES OF FISHING QUALITY

It has been customary in creel-census studies to use the number of fish caught per hour of fishing as a measure of the quality of fishing. For comparisons of samples of the same type of fishing, this index is probably the best that we have. Most investigators have failed, however, to analyze the data by well known statistical procedures which would have improved their evaluation of differences in fishing quality.

The unit of fishing quality employed in this report is the catch per hour per fishing trip. The statistical tools employed have been limited to the mean and the standard error of the mean. All fishing trips have been used in the computation of these statistics, even though inclusion of the unsuccessful trips results in highly skewed distribution of the values. An additional index of fishing quality employed is the percentage of successful fishing trips (*i.e.*, trips on which the angler caught at least one legal-sized trout). These values are usually given in conjunction with the mean catch per hour per angler.

In summary of data on fishing quality in different sections of the Pigeon River for the 3-year period, 1949–1951 (Table 3), the records for fish from

TABLE 3.—*Fishing quality in the Pigeon River, 1949 to 1951 inclusive, for brook, brown, and rainbow trout combined*
[Hatchery trout were planted in Sections B and C]

Stream section and fishing statistics	Year and source of trout					
	1949		1950		1951	
	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
Section A						
Mean catch per hour	0.125	0.161	0.331	0.135	0.144	0.259
Standard error of mean	0.108	0.021	0.032	0.016	0.021	0.029
Percentage of successful fishing trips	22.3	23.8	36.9	24.6	20.4	31.6
Section B						
Mean catch per hour	0.334	0.095	0.650	0.124	0.694	0.123
Standard error of mean	0.024	0.009	0.047	0.012	0.042	0.009
Percentage of successful fishing trips	40.1	19.2	46.9	20.5	45.7	19.9
Section C						
Mean catch per hour	0.287	0.135	0.488	0.181	0.760	0.024
Standard error of mean	0.020	0.011	0.042	0.014	0.033	0.005
Percentage of successful fishing trips	39.7	27.5	41.4	30.5	63.7	4.0
Section D						
Mean catch per hour	0.025	0.036	0.030	0.328	0.036	0.062
Standard error of mean	0.006	0.028	0.006	0.030	0.009	0.013
Percentage of successful fishing trips	6.6	40.9	7.5	38.5	7.2	13.4
All Sections						
Mean catch per hour	0.244	0.150	0.441	0.180	0.581	0.101
Standard error of mean	0.012	0.007	0.023	0.008	0.022	0.006
Percentage of successful fishing trips	32.6	26.1	36.6	27.3	44.3	15.4

hatchery plantings and for naturally spawned fish have been tabulated separately. The differences in the quality of fishing for hatchery trout between sections and between years are not directly comparable but reflect, to a large degree, differences in the catchability of the species of trout planted. Additional sources of bias are the change in regulations made in 1951, and a concentration of the plantings in 1950 and 1951 during the season in which favorable water temperatures prevailed. Thus, in comparisons of the returns from the 1949 plantings with those of later years, it must be remembered that the success of the angler was materially increased in 1950 and 1951 by the substitution of brook and rainbow trout for brown trout and by making the plantings during periods of favorable

water temperatures. Fishing intensity did not change sufficiently in the 3 years to have had a substantial effect, *per se,* on the average angling quality. These matters are treated in more detail in later sections.

The data for the wild fish indicated a rather stable fishery of low yield during the 3 years. The catch and rate of exploitation were similar for the same species from year to year, but brook trout were markedly easier to catch than brown trout (Cooper, 1952). The drop in fishing quality in 1951 for Sections C and D was due in great part to the change in fishing regulations from a 7- to a 9-inch minimum size limit. In these sections the limit also was reduced in 1951 from 15 to 2 per day. This reduction in daily limit was accompanied by a noticeable decrease in fishing effort in the unplanted section (D) but a large increase in the planted section (C).

Brook trout outnumbered brown trout in the catch about 3:1. The residual fall population of legal-sized fish, according to estimates made through the use of electrofishing devices, was composed of about 3 brown trout to 1 brook trout. On the whole, fishing for wild trout was poor, averaging less than 1 fish for 5 hours of effort It is believed that this low figure was due to the heavy annual fishing pressure and also to the depleted condition of the native trout population.

Comparison of Results from "Spot-" and "Scatter-planting"

In the past, much public criticism has been directed against "spot-planting" legal trout, *i.e.,* liberating large numbers of fish at a single locality in the stream. The critics have held that this type of planting made fishing too easy and too artificial, and that only a few persons benefited from the plantings. To counteract this criticism, valid or invalid, Michigan has developed methods of scattering the fish as widely as possible over the stream, usually from a boat with live wells or from a portable live crate. A group of preliminary experiments (Shetter, 1947) conducted to evaluate returns from the two types of plantings could not demonstrate any advantage of scatter-planting over spot-planting.

In 1949 and 1950, many individual experiments were conducted to compare the returns from spot- and scatter-planting methods. Analysis of returns from these individual plantings indicated that they could be combined without serious bias. A few more fish were recovered from the spot-planted than the scatter-planted fish; spot-plants resulted in a slightly greater number of successful fishing trips than did scatter-plants; and the numbers of different anglers who benefitted from the two planting methods were almost equal (Table 4).

Trout that had been scatter-planted did not contribute to the catch for a longer period of time than did spot-planted trout. As is shown later, the rate at which plantings were depleted was more dependent on the species of trout than on the method of planting.

In each of the three seasons, 4,500 trout were planted in approximately 2.3 miles of stream. The number of individual plantings ranged from 3 plantings in 1950 to 5 in 1949 and 7 in 1951. The practice of planting

TABLE 4.—*Relationship between method of planting legal-sized trout and returns to anglers*

Item	Year and method of planting			
	1949		1950	
	Spot	Scatter	Spot	Scatter
Total number of fish planted	2,250	2,250	2,250	2,250
Total number of fish recovered	931	706	1,049	933
Number of successful fishing trips	552	504	466	445
Number of different anglers sharing the catch	414	399	273	283

smaller numbers of fish at more frequent intervals proved to be more effective in spreading the fish over more fishing trips and among more individual anglers than the scatter-type planting method. In effect, increasing the number of plantings is scatter-planting in time rather than in space. More fishermen shared in the catch and more fishing trips were successful when many individual plantings were made (Table 5).

TABLE 5.—*Relationship between number of individual plantings and returns to anglers*

Year and number of plantings	Total number of fish planted	Total number of fish recovered	Percentage of total fishing trips successful	Percentage of total individual anglers successful
1950, 3 plantings	4,500	2,313	36.6	37.2
1949, 5 plantings	4,500	1,655	41.0	35.9
1951, 7 plantings	4,500	2,677	43.8	41.5

EFFECT OF DAILY LIMITS ON DISTRIBUTION OF TROUT IN CATCH

Daily creel limits for trout are based on the assumption that the fish saved by limiting the catch will be available to, and be used by, other anglers or to the same anglers on additional days. Actually, the creel limit is a penalty imposed on the more skillful or more fortunate anglers which is presumably justified as a means of insuring a more nearly equal sharing of the total production of the lake or stream. The effect of daily creel limits was tested by changing fishing restrictions on different sections of the Pigeon River from year to year (Table 6).

TABLE 6.—*Relationship between creel limits and number of trout taken per fishing trip*

Stream section, creel limit, and year	Percentage of total fishing trips resulting in capture of indicated numbers of trout per fishing trip			
	None	1 to 5	6 to 10	11 to 15
Section B				
5 trout per day, 1949, 1950, 1951	49.0	50.8	0.2	....
Section C				
15 trout per day, 1949, 1950	48.3	42.7	6.4	2.6
2 trout per day, 1951	36.3	63.7	....	....

The hatchery plantings in Sections B and C furnished 78 percent of the fishing in these sections or about 3½ times as much as the wild fish. This heavy rate of stocking attracted a much higher fishing intensity in these sections than in unplanted ones, yet one would expect that a large proportion of the anglers would catch fish in the planted sections. Actually, about half of the fishing trips were unsuccessful, and limiting the daily catch to 5 trout instead of 15 trout in Section C had little effect on reducing the percentage of unsuccessful anglers. When the daily limit was reduced further to 2 trout and stocking was carried out at a rate of 400 legal fish per acre per year, 36 percent of the fishing trips were still unsuccessful (Table 6).

Comparison of Returns from Different Species

Plantings of rainbow trout and brook trout gave much higher returns to the fishermen than did equal numbers of brown trout (Table 7). Returns from individual plantings ranged from 9.7 to 82.0 percent. Plantings made in June and July 1949, when water temperatures were high, resulted in poor returns for all three species. During these hot-weather periods mortality or predation must have been high, although it was impossible to find sufficient numbers of dead or dying fish to explain the unaccounted high loss from these particular plantings. Movement out of the planted area was also too slight to be an important factor during hot weather, although movement of the planted fish, because of cold water, was demon-

Table 7.—*Returns from individual plantings of legal-sized trout of three species from the Pigeon River*

[Recoveries made during same season in which trout were planted]

Planting date	Average maximum water temperature (F.°) for 7 days following planting date	Brook trout		Brown trout		Rainbow trout	
		Number planted	Percentage recovered	Number planted	Percentage recovered	Number planted	Percentage recovered
April 28, 1949...	55	300	71.0	300	45.0	300	74.3
May 25, 1949...	56	300	41.3	300	36.0	300	69.7
June 29, 1949...	75	300	9.7	300	19.3	300	20.0
July 27, 1949...	75	300	18.0	300	10.7	300	25.7
Aug. 17, 1949...	71	300	60.0	300	17.0	300	34.0
April 26, 1950...	45	1,000	35.8	...	....	1,000	36.5
June 1, 1950....	65	500	45.6	...	....	500	60.2
June 1, 1950[1]...	65	500	64.0	...	....	500	82.0
Aug. 8, 1950....	72	250	60.0	...	....	.....	....
Aug. 8, 1950[1]...	72	250	72.4	...	....	.....	....
April 19, 1951...	42	.....	....	...	....	644	26.9
May 3, 1951....	55	.....	....	...	....	644	70.8
May 17, 1951...	62	.....	....	...	....	646	72.1
May 31, 1951...	61	.....	....	...	....	642	67.4
June 14, 1951...	68	.....	....	...	....	644	70.5
July 26, 1951...	72	.....	....	...	....	644	55.7
Aug. 9, 1951....	65	.....	....	...	....	636	69.5

[1] Plantings were marked by fin-clipping. All others were jaw-tagged

strated to have been the principal reason for low returns from the plantings made during April 1950 and 1951.

Returns from plantings made in April 1950 and 1951 are not considered complete because of the impossibility of contacting many anglers who fished outside the research area and because of the demonstrated movement of these plantings out of the area.

The returns of brook and rainbow trout planted under favorable conditions of water temperature and heavy fishing pressure averaged higher than 50 percent, and the average for the 3,856 rainbow trout planted in 1951 (excluding the one planting deliberately made during cold weather) exceeded 67 percent (Table 7).

Rainbow trout survived to successive seasons nearly as well as did brown trout, although for both species the survival was small (Table 8). The

TABLE 8.—*Recoveries and survival of legal-sized trout planted in the Pigeon River during open seasons of 1949, 1950, and 1951*
[Percentage of total planted given in parentheses]

Item	Year and species of trout planted					
	1949			1950		1951
	Brook	Brown	Rainbow	Brook	Rainbow	Rainbow
Number planted	1,500	1,500	1,500	2,500	2,000	4,500
Number recovered during first season	600 (40.0)	384 (25.6)	671 (44.7)	1,237 (49.5)	1,076 (53.8)	2,677 (59.5)
Estimated number remaining, first fall	80 (5.3)	452 (30.1)	380 (25.3)	75 (3.0)	151 (7.6)	374 (8.3)
Number recovered during second season	0	33 (2.2)	34 (2.3)	2 (0.08)	16 (0.8)	.....
Estimated number remaining, second fall	0	31 (2.1)	2 (0.13)	0	4 (0.2)	.....
Number recovered during third season	0	1 (0.07)	0	.....	.....	.....
Estimated number remaining, third fall	0	4 (0.27)	0	.....	.....	.....

fact that the legal-sized hatchery trout grew less than an inch per year in the stream after planting decreased the value of these overwinter recoveries.

Estimates of the number of trout surviving from the open-season plantings were made each September by use of electrofishing methods. This estimate allowed some deduction as to the survival from residual fall populations of planted fish. Returns in the next summer from these residual fall populations of brook, brown, or rainbow trout varied from 0.0 to 10.6 percent, with brook trout never exceeding 2.7 percent. One brown trout from an original planting of 1,500 was recaptured in the second season following planting (Table 8).

COMPARISON OF RATE OF RECOVERY OF TAGGED AND FIN-CLIPPED FISH

In June and August 1950, due to a shortage of jaw tags, it was necessary to fin-clip half of the fish in each planting. Advantage was taken of this

situation to compare returns from tagged and fin-clipped fish. Several types of plantings were made (brook trout, spot-planted; brook trout, scatter-planted; rainbow trout, spot-planted; rainbow trout, scatter-planted). In each planting half of the fish were tagged and half were fin-clipped. In all of the plantings, fin-clipped fish were recovered in larger numbers than were tagged fish. This difference was especially apparent during the first week as evidenced by the higher values of Chi-square obtained for this period (Table 9). Adjusted Chi-square values were computed according to the method outlined in Snedecor (1946, section 1.13).

TABLE 9.—*Comparison of rate of recovery of tagged and fin-clipped trout from the Pigeon River*

Species and date of planting	Method of planting	Number of trout planted		Number of recoveries		Adjusted Chi-square
		Tagged	Fin-clipped	Tagged	Fin-clipped	
Recoveries during first week after planting						
Rainbow trout June 1, 1950	Spot	250	250	34	63	8.08
	Scattered	250	250	36	85	19.04
Brook trout June 1, 1950	Spot	250	250	104	141	5.29
	Scattered	250	250	49	73	4.34
Brook trout August 8, 1950	Spot	125	125	44	73	6.70
	Scattered	125	125	29	45	3.04
Total recoveries from plantings						
Rainbow trout June 1, 1950	Spot	250	250	164	203	3.93
	Scattered	250	250	137	207	13.84
Brook trout June 1, 1950	Spot	250	250	127	175	7.32
	Scattered	250	250	101	145	7.52
Brook trout August 8, 1950	Spot	125	125	73	101	4.19
	Scattered	125	125	77	80	0.02

No other studies of differences in rate of recovery between tagged and fin-clipped fish were made. However, if differences of this magnitude can be demonstrated by further data to be consistent, a major bias would be involved in the use of tagged fish to determine returns to anglers. The total returns of the 500 fin-clipped rainbow trout planted on June 1, 1950, amounted to 82 percent. This value is considerably higher than the 60 percent of the tagged rainbow trout planted at the same time and fished for under the same conditions.

Movement Following Planting

In choosing the species of trout to be used in supplemental planting, the direction and amount of movement of the fish following release must be considered. Of the four experimental stream sections, trout were planted in the center two only. Since complete records of fishing were maintained

for all sections, it was possible to detect any tendency for the fish to move either upstream or downstream. Examination of the data for the individual plantings indicated general agreement in the pattern of movement except for certain plantings made in the early season during periods of cold water. Consequently all but these early-season plantings were combined for the entire 3-year period in the preparation of Table 10.

During the "warm-water" period (temperatures of 55° to 75°F.) when most plantings were made, more fish of all three species of trout remained in the central sections than moved either downstream or upstream. Great-

TABLE 10.—*Movement of hatchery trout following planting in the Pigeon River as shown by angling recoveries*

[Trout caught in section in which planted are recorded as no movement. Water temperatures given are average maximum water temperatures for the 7 days following each planting]

Planting dates	Water temperature Range F°.	Average number of trout caught from each planting per 1,000 hours of angling		
		Moved downstream	No movement	Moved upstream
Brook trout				
April 26, 1950	45	41.6	13.9	1.3
All other planting dates	55 to 75	23.8	34.1	2.7
Brown trout				
All planting dates	55 to 75	0.5	26.3	2.2
Rainbow trout				
April 26, 1950; April 19, 1951	42 to 45	37.8	9.2	0.4
All other planting dates	55 to 75	10.4	88.3	2.9

est movement was exhibited by brook trout which yielded 23.8 fish per 1,000 hours of angling downstream as compared with 34.1 fish per 1,000 hours in the central sections; upstream movement of brook trout was small, however (only 2.7 fish caught per 1,000 hours of angling). Brown trout tended to remain near the planting site, but rainbow trout showed some tendency (but not as strong as with the brook trout) toward downstream movement.

The pattern of movement was entirely different for brook trout and rainbow trout planted at times of low water temperatures (42° to 45°F.). Both exhibited very strong tendencies toward downstream movement when they were planted in cold water.

To obtain more detailed information on the effects of low temperatures on fish movement than was to be had from records of anglers' catches, intensive electrofishing was carried on after the planting of 644 rainbow trout on April 19, 1951 (water temperature, 43°F.), and of 644 rainbow trout on May 3, 1951 (temperature, 54°F.). Within one-half hour of

the planting time, electrofishing was begun approximately 1 mile below the downstream planting site, and the numbers of trout from the plantings were recorded for successive 200-yard intervals until the entire experimental section was traversed. This single trip through the area required two working days. In this manner, the distribution of the hatchery trout in the stream was indicated for three periods following each planting. The electrofishing data showed a rapid downstream movement of the trout planted at a time when the water temperature was 43°F., with some trout moving 1,200 to 1,600 yards in three hours. Trout planted when water temperatures were above 50°F. showed little inclination to move from the planting site. Data from the plantings of April 19 and May 3, 1951, only are presented (Figure 2). Fish of subsequent plantings in 1951 exhibited movements similar to those of the May 3 planting.

Length of Time Plantings Influence the Catch

Legal-sized brook, brown, and rainbow trout, planted in a stream subjected to heavy fishing pressure, contributed to the catch for a relatively short time. Recoveries from plantings made in the Pigeon River for the past 3 years have been tabulated according to the time spent in the stream after planting (Table 11). Brook trout were caught the most readily; 96 percent of the recoveries occurred during the first 40 days of liberty.

Table 11.—*Length of time hatchery trout influence the catch*
[Only the recoveries from plantings made in April, May, and June are tabulated]

Species of trout planted	Number planted	Item	Number of days following planting						
			0-20	21-40	41-60	61-80	81-100	101-120	121-140
Brook	2,900	Number recovered....	1,011	199	36	12	3	1	0
		Percentage of planting.	34.9	6.9	1.2	0.4	0.1	0.03	0.0
		Percentage of total recoveries in interval..	80.1	15.8	2.9	1.0	0.1	0.1	0.
Brown	900	Number recovered....	124	97	39	21	10	8	1
		Percentage of planting.	13.8	10.8	4.3	2.3	1.1	0.9	0.1
		Percentage of total recoveries in interval..	41.4	32.3	13.0	7.0	3.3	2.7	0.3
Rainbow	6,120	Number recovered....	1,897	892	376	198	100	58	26
		Percentage of planting.	31.0	14.6	6.1	3.2	1.6	0.9	0.4
		Percentage of total recoveries in interval..	53.6	25.1	10.6	5.6	2.8	1.6	0.7

For brown trout and rainbow trout these values were 74 percent and 79 percent, respectively. Recoveries past one winter were minimal for brown and rainbow trout and practically nonexistent for brook trout (Table 8). In all of the plantings there was a considerable unexplained loss; this loss was greatest when poor conditions for exploitation by anglers prevailed over the initial 20 to 40 days following planting.

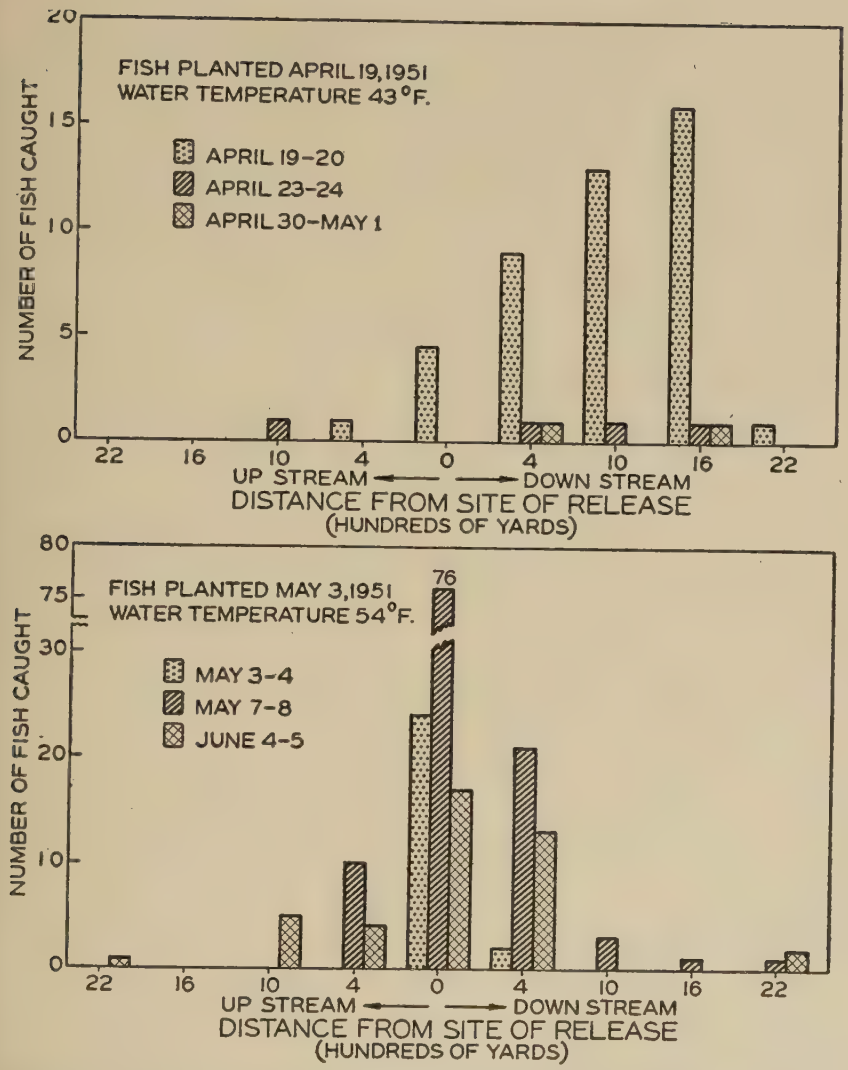

FIGURE 2.—Movement of hatchery-reared rainbow trout following planting in the Pigeon River, 1951. Fish were recovered by a direct-current electrofishing device.

EFFECTS OF PLANTING LEGAL-SIZED HATCHERY FISH ON THE CATCH OF WILD FISH

As a result of previous experiments in Michigan on plantings of brook and rainbow trout, Hazzard and Shetter (1939) concluded that plantings of legal-sized hatchery fish brought about marked increases in the catch

of wild fish. The cause-and-effect relationship was held to be operative only for individual species; *i.e.,* plantings of brook trout affected the catch of wild brook trout and not of the other two species, . . . In a later paper (1941) the same authors further limited the cause-and-effect-relationship described above to those situations in which individual plantings were at the rate of more than 160 legal trout per mile of stream. They reached this conclusion because of their failure to demonstrate the expected result in plantings in which the stocking rate was between 100 and 160 legal trout per mile.

The stocking program for the Pigeon River for 1949, 1950, and 1951, in conjunction with the permit system of fishing, afforded an opportunity to evaluate the effect of plantings of hatchery trout upon the catch of wild trout. When fluctuations of the catch per hour per angler of hatchery fish were compared to those of wild fish, without regard to species planted or numbers in the individual plantings, no correlation was apparent (Figure 3). Furthermore, the data indicated that plantings of brook trout at rates ranging from 216 to 431 trout per mile had no detectable effect on the catch of wild brook trout (Table 12). Nor can the views of Chamberlain (1943) that the planting of hatchery trout protects the wild fish be justified on the basis of our experiments. The increase of fishing pressure that followed the planting of hatchery trout had a tendency to lower the catch per hour for wild fish, but the total exploitation for the

TABLE 12.—*Effect of planting hatchery brook trout on the catch of wild brook trout in the Pigeon River, 1950*[1]

[Plantings made on April 26, 1950, at 431 trout per mile; on June 1, 1950, at 431 trout per mile; and on August 8, 1950, at 216 trout per mile]

Weekly period	Total hours fished	Hatchery fish		Wild fish	
		Number caught	Catch per hour[2]	Number caught	Catch per hour[2]
April 29-May 5	197.5	1	0.01	0	0.00
May 6-12	91.5	15	0.16	6	0.05
May 13-19	319.5	111	0.35	42	0.13
May 20-26	217.5	34	0.16	54	0.25
May 27-31	372.5	17	0.05	44	0.12
June 1-7	334.0	353	1.06	34	0.10
June 8-14	314.0	84	0.27	41	0.13
June 15-21	241.0	50	0.21	33	0.14
June 22-28	191.0	16	0.08	22	0.12
June 29-July 5	279.0	11	0.04	35	0.13
July 6-12	150.5	2	0.01	28	0.19
July 13-19	149.0	3	0.02	10	0.07
July 20-26	74.0	1	0.01	9	0.12
July 27-August 2	92.0	1	0.01	5	0.05
August 3-7	67.5	0	0.00	15	0.22
August 8-14	231.5	178	0.77	19	0.08
August 15-21	145.5	41	0.28	10	0.07
August 22-28	234.5	45	0.19	17	0.07
August 29-September 4	221.5	29	0.13	26	0.12
September 5-10	97.0	11	0.11	14	0.14

[1] Coefficient of correlation between catch per hour of hatchery fish and catch per hour of wild fish computed to be 0.12

[2] Mean of the catch per hour of individual fishermen

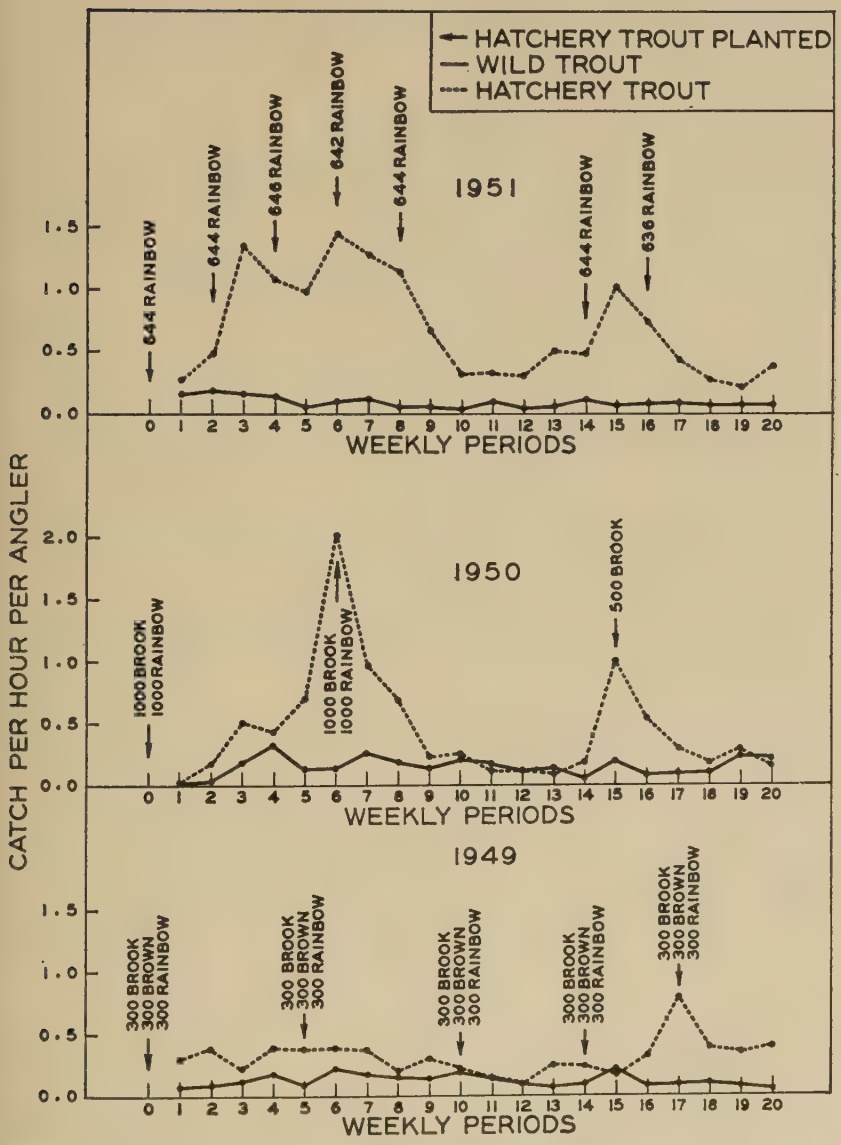

FIGURE 3.—A Comparison of the quality of fishing for hatchery trout (broken line) and wild trout (solid line) in the Pigeon River in 1949, 1950, and 1951.

season was unchanged. It appeared, for the brook trout at least, that comparatively few fishing trips materially reduce the numbers of trout of legal size, and that additional fishing trips were consequently less successful.

Acknowledgments

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Literature Cited

Chamberlain, Thomas, K.
1943. Research in stream management in the Pisgah National Forest. Trans. Am. Fish. Soc. Vol. 72, (1942) pp. 150–176.

Cooper, Edwin L.
1952. Rate of exploitation of wild eastern brook trout and brown trout populations in the Pigeon River, Otsego County, Michigan. Trans. Am. Fish. Soc. Vol. 81, pp. 224–234.

Hazzard, Albert S. and David S. Shetter
1939. Results from experimental plantings of legal-sized brook trout (*Salvelinus fontinalis*) and rainbow trout (*Salmo irideus*). Trans. Am. Fish. Soc. Vol. 68, (1938) pp. 196–210.

Shetter, David S.
1947. Further results from spring and fall plantings of legal-sized, hatchery-reared trout in streams and lakes of Michigan. Trans. Am. Fish. Soc. Vol. 74, (1944) pp. 35–58.

Shetter, David S. and Albert S. Hazzard
1941. Results from plantings of marked trout of legal size in streams and lakes of Michigan. Trans. Am. Fish. Soc. Vol. 70, (1940) pp. 446–468.

Snedecor, George W.
1946. Statistical methods. The Collegiate Press, Inc., Ames, Iowa. XVI, 485 pp.

NITROGEN AND PHOSPHORUS CONCENTRATIONS IN FERTILIZED AND UNFERTILIZED FARM PONDS IN CENTRAL MISSOURI [1]

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ABSTRACT

The limnology of six typical Missouri farm ponds, where fish growth rates had been determined, was investigated. Particular emphasis was directed toward a measurement of the important nutrient elements, nitrogen and phosphorus, in an effort to evaluate the processes associated with fertilization and establish the nutrient factor or factors most clearly related to fish production for Missouri ponds.

Comparison of the physical and chemical data for these fertilized and unfertilized ponds suggests that the limiting factor in productivity was soluble phosphate. Yearly mean concentrations of phosphate at the surface ranged from 0.016 to 0.028 p.p.m. in the fertilized ponds and from 0.010 to 0.016 p.p.m. in the unfertilized ponds. Daily phosphorus analyses showed good correlation between concentrations of phosphate and plankton production. Each addition of fertilizer was followed by a rapid settling out which resulted in bottom phosphate concentrations which, in one pond, were as much as 10 times as great as the surface concentrations. This phosphate is confined to the bottom by a stable summer stratification in Missouri. Phosphorus added as fertilizer was found to be utilized within one week and on occasion within 24 hours depending on the degree of biological activity.

The occurrence of filamentous algae was correlated with increases in light penetration and soluble phosphate. A pond with filamentous algae showed a much lowered response to fertilization suggesting a removal of nutrients due to absorption by the algal mat.

Nitrogen was not limiting for algal growth in these ponds. Unfertilized ponds showed higher concentration of inorganic nitrogen than did the fertilized ponds. This increased concentration of nitrogen was attributed to the presence of the legume *Lespedeza cuneata* (sericea lespedeza) on the watershed of the unfertilized pond. Quantitative data on nitrogen inflow from the watersheds carrying growths of sericea lespedeza show significantly higher concentrations of inorganic nitrogen in the runoff water.

INTRODUCTION

One of the procedures utilized for the attainment of maximum fish production in farm ponds has been the application of inorganic fertilizers.

[1] Contribution from the Missouri Cooperative Wildlife Research Unit: U.S. Department of the Interior, Fish and Wildlife Service; Wildlife Management Institute; Missouri Conservation Commission; Edward K. Love Foundation; and University of Missouri cooperating. The author wishes to acknowledge the advice of Dr. Robert S. Campbell of the University of Missouri. Special thanks also are due to Paul G. Barnickol and Ralph M. Burress of the Missouri Conservation Commission for critical review of the manuscript.

In soils of low agricultural productivity, water fertilization to increase the growth of pond fish is necessary to compensate for the lack of natural soil fertility. Since poor soils are characteristic of some areas of Missouri, pond fertilization has been included in the farm-pond management program although recommended only where increased production of fish is desirable. The results of fertilization may be unfavorable because of excessive algal development and they are usually difficult to interpret. In an effort to explain these variable results, the limnology of these ponds was investigated with particular emphasis on the measurement of nitrogen and phosphorus which were assumed to be important nutrient elements.

Six experimental ponds were under observation for 14 months. These ponds were considered typical of Missouri farm ponds in that the depth did not exceed 10 feet and the area of each was one-half acre or less. Two of the ponds were fertilized with a 4-12-4 (N-P-K) inorganic commercial fertilizer at the rate of 1,000 pounds per acre per year. Growth of the fish had been determined by Burress [2] and phytoplankton production in three of the ponds by Proctor.[3] A greater growth rate of fish and a higher production of phytoplankton was reported for the fertilized ponds. The present study emphasized: 1. A comparison of nutrient concentrations in fertilized and unfertilized ponds; and 2. A measure of the succession of events which occurred between successive additions of fertilizer.

Comparison of Fertilized and Unfertilized Ponds

Although extensive limnological data were secured, only the material on nitrogen and phosphorus is presented in this paper.

The physical and chemical factors on which data were obtained for the experimental ponds included alkalinity, turbidity, carbon dioxide, mineral content, nitrogen and phosphorus concentration. The only consistent difference between the fertilized and unfertilized ponds was in the amount of phosphorus present.

From the mean yearly phosphorus concentrations in the several ponds (Table 1) it will be seen that the outstanding difference between the fertilized and unfertilized ponds lies in a higher concentration of soluble phosphate on the bottom of the former. Surface concentrations also are higher in the fertilized ponds although the difference is not as great as in the bottom water. Total phosphorus, presumably the best indicator of the potential phosphorus fertility, is found to be higher generally in the fertilized ponds. Since the ratio of the different forms of phosphorus is constantly changing, and since the soluble phosphate is the only form directly available to plankton, a more reliable index to the actual fertility may be found in the percentage concentration of available phosphate

[2] Burress, Ralph M. 1949. The growth rates of bluegills and largemouth black bass in fertilized and unfertilized ponds in central Missouri. Unpublished Master's dissertation, University of Missouri.

[3] Proctor, Vernon W. 1951. A survey of the phytoplankton of three central Missouri farm ponds. Unpublished Master's dissertation, University of Missouri.

calculated from determinations of total phosphorus (Table 1). In this study the surface waters showed concentrations of over 21 percent available phosphate for the fertilized ponds; in the unfertilized ponds this percentage ranged from a low of 13 percent to a high of 19 percent available phosphate. Bottom concentrations of soluble phosphate are higher than surface levels in both fertilized and unfertilized ponds. It should be noted that in the fertilized ponds more than one-third of the total phosphorus on the bottom is in the form of phosphates whereas in the unfertilized ponds only about one-fifth of the total phosphorus is in the form of phosphates.

TABLE 1.—*Mean yearly phosphorus concentration (p.p.m.) and the percentage (in parentheses) contribution of the two fractions of total phosphorus, all ponds, 1951-1952*

Item	Fertilized ponds		Unfertilized ponds			
	Pond 1	Pond 2	Pond 4	Pond 6	Pond 7	Pond 8
Phosphate phosphorus						
Surface	0.016 (21)	0.028 (21)	0.016 (19)	0.010 (14)	0.011 (16)	0.012 (15)
Bottom	0.049 (35)	0.083 (47)	0.025 (21)	0.021 (22)	0.019 (21)	0.017 (22)
Organic phosphorus						
Surface	0.060 (79)	0.102 (79)	0.068 (81)	0.062 (86)	0.060 (84)	0.068 (85)
Bottom	0.090 (65)	0.094 (53)	0.093 (79)	0.076 (78)	0.070 (79)	0.061 (78)
Total phosphorus						
Surface	0.076 (100)	0.130 (100)	0.084 (100)	0.072 (100)	0.071 (100)	0.080 (100)
Bottom	0.139 (100)	0.177 (100)	0.118 (100)	0.097 (100)	0.089 (100)	0.077 (100)

The Role of Nitrogen in Pond Productivity

Nitrogen apparently did not limit fish production in these ponds. In the unfertilized ponds where growth of fish was poor, nitrogen was found in greater concentrations than in the fertilized ponds. It appeared that the explanation was found not in a greater demand for and utilization of nitrogen in the fertilized ponds, but rather from an increased nitrogen supply to the unfertilized ponds through plantings of legumes on their watersheds.

Results of analysis of the watershed soils of these ponds showed that the presence of sericea lespedeza, *Lespedeza cuneata,* resulted in significantly higher concentrations of organic matter and a greater potential source of nitrogen in the soil. Ponds in these soils have a more abundant supply of inorganic nitrogen in the water than do those ponds without this plant in their watersheds. Unfertilized ponds with sericea lespedeza in their watersheds maintained consistently higher levels of dissolved inorganic nitrogen than did those fertilized ponds that lacked the legume in their watersheds.

During the winter months, all the ponds had high levels of nitrate. Dur-

ing the summer of 1951 the nitrate concentration was significantly higher in the ponds with legume-bearing watersheds. In the summer of 1952, however, these differences were not present. It is assumed that the similarity of nitrogen levels in the different ponds in 1952 was the result of an unusually low rainfall so that little nitrogen fertilization was realized from the legume-bearing watersheds.

In 1951, analyses made in the shoal area of the ponds following a rain showed increases of inorganic nitrogen presumably from runoff from the watershed grown to sericea lespedeza. In order to obtain quantitative data on the nitrogen inflow from different watershed types, three lysimeters from the University of Missouri Soil Conservation Farm were installed. Two were placed on watersheds with sericea lespedeza and the third on the watershed without sericea. Ten-feet-square plots with comparable slope were enclosed. The results of the analyses of the runoff during the summer of 1952 (Table 2) demonstrate that significantly higher inflow of nitrogen is found from the legume bearing watersheds than from areas without legumes.

This study suggests that planting of sericea lespedeza on the watershed offers an efficient method of supplying nitrogen to farm ponds.

TABLE 2.—*Nitrogen analyses on runoff water from watersheds with and without legumes, 1952*

Date	Form of Nitrogen	Pond [1]2	Pond 4	Pond 6
June 22	Nitrate	0.500	0.611	1.620
	Nitrite	0.030	0.080	0.040
July 8	Nitrate	0.420	0.900	1.300
	Nitrite	0.015	0.031	0.032
	Ammonia	0.175	0.201	0.225
July 14	Nitrate	0.470	0.660	1.720
	Nitrite	0.090	0.110	0.110
	Ammonia	0.275	0.225	0.155

[1] Watershed without legumious growth

The Role of Phosphorus in Pond Productivity

Since phosphorus was considered the limiting factor in pond productivity, considerably more time was devoted to its measurement. During the first summer, determinations were made at intervals of approximately 1 week. Since rapid and extensive fluctuations were encountered at this time, a program of daily analyses of a smaller number of ponds was inaugurated the second summer in order to understand more fully the nature of the fluctuations, especially in the fertilized ponds. Three ponds, two fertilized and one unfertilized, were examined for total and soluble phosphorus. The data from these analyses are presented graphically in Figures 1 and 2 for the fertilized ponds and in Figure 3 for the unfertilized pond. Plankton density was inferred from light penetration as measured with a Secchi disc.

Following fertilization, a definite relationship was found between plankton density and concentrations of phosphate (Figs. 1 and 2). When plankton blooms were absent, an application of fertilizer resulted in an appreciable increase of dissolved phosphate in the pond. However, when

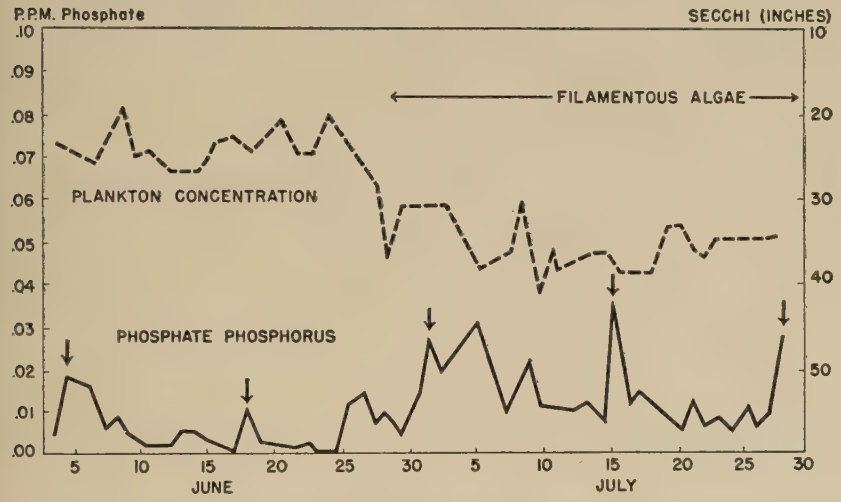

FIGURE 1.—Surface concentrations of phosphate phosphorus (p.p.m.; solid line) and plankton abundance in terms of light penetration (inches; broken line) in Pond 1, summer of 1952. Arrows indicate day of fertilizer application.

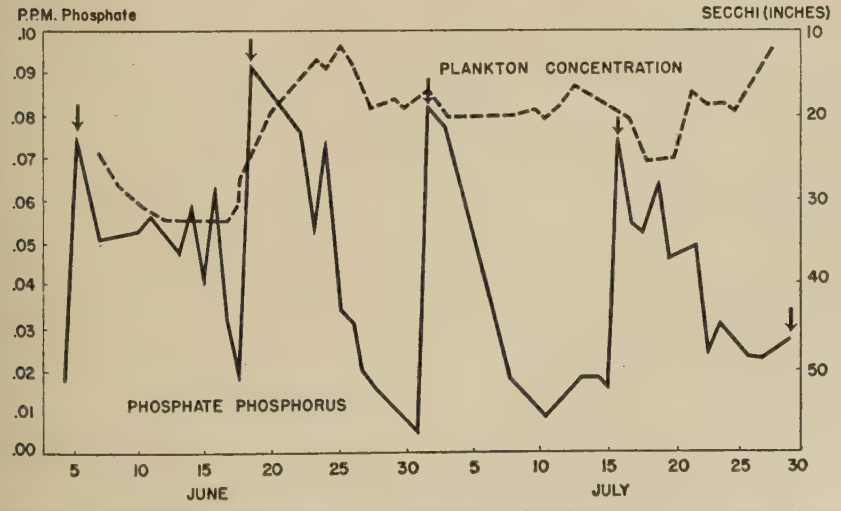

FIGURE 2.—Surface concentratons of phosphate phosphorus (p.p.m.; solid line) and plankton abundance in terms of light penetration (inches; broken line) in Pond 2, summer of 1952. Arrows indicate day of fertilizer application.

a plankton bloom was present, an application of fertilizer resulted in a smaller increase of phosphate. With persisting blooms, progressively smaller increments of phosphate were observed with successive additions of fertilizer; moreover, the increase resulting from each addition persisted for a shorter time. Upon subsequent disappearance of the plankton bloom, phosphate concentrations increased immediately and an appreciable increase again was found following the addition of fertilizer.

It is suggested that this correlation is significant in showing phosphorus to be a limiting factor in plankton production. It would seem that closer correlations between plankton abundance and phosphate levels would be observed rarely because of the complexity of factors involved in the physiological responses of the algal population. Culture experiments (Ketchum, 1939; Chu, 1943; and Rodhe, 1948) indicated a complexity of responses of dense algal populations to different nutrient levels. Rapid absorption of nutrients and ability of the cells to exist and multiply during periods of low supply at the expense of cellular concentrations of the nutrients were shown; also demonstrated was the ability of the cells to make up the phosphorus debt later at higher concentrations. These culture experiments and our observations in Missouri farm ponds suggest that changes in the phosphorus concentrations are so rapid and of such a magnitude as to make daily checks desirable for studies of the type mentioned above. Observations at greater intervals of time might allow significant changes to pass unnoticed.

The initial increase of phosphorus following fertilization was found to persist for periods varying from less than 24 hours to a week. The duration of the increase is apparently controlled by the degree of biological activity in the pond (Figs. 1 and 2). The decrease of phosphorus in the surface waters is accompanied by an increase of phosphate on the bottom indicating incomplete solution and settling out of the fertilizer. Bottom concentrations of phosphate were found to be 10 times higher than surface concentrations in one of the fertilized ponds. These high concentrations are restricted to the bottom water by summer stratification. Under Missouri conditions most farm ponds 8 feet deep or over are continuously stratified during the summer.

The occurence of filamentous algae has been responsible for the failure of many fertilization programs. This situation is likely to affect the public acceptance of fertilization programs, since the deleterious effects of the algae overshadow any potential gain from fertilization. One of the fertilized ponds included in this study was characterized by heavy growths of filamentous algae throughout the period of observation. It may be noted from Figure 1 that during July, when the previously recorded bloom of unicellular algae disappeared from Pond 1, the nutrients increased to twice the level found in the previous month when the bloom was present. With the loss of the heavy algal population, Secchi readings changed from approximately 2 feet to more than 3 feet. In a period of about four days after this increase in light and nutrients, roughly one-third of the water

area of the pond became covered with mats of filamentous algae, mostly of the genera *Cladophora* and *Pithophora*. During the summer of 1951 similar changes preceded the development of the mat although at a date approximately a month later. Swingle (1947) also has correlated the development of the algal mat with increased light penetration. The increase of phosphate noted in Pond 1 was assumed to be due to the decomposition of unicellular plankton bloom.

The response to fertilization was never as geat in Pond 1 as in the other fertilized pond. Since the two received equal amounts of the same type of fertilizer, it would appear that the availability of the phosphate was reduced by the algal mat.

Phosphate-phosphorus concentrations in the water of unfertilized Pond 6, (Fig. 3) were low in contrast to concentrations in the fertilized ponds

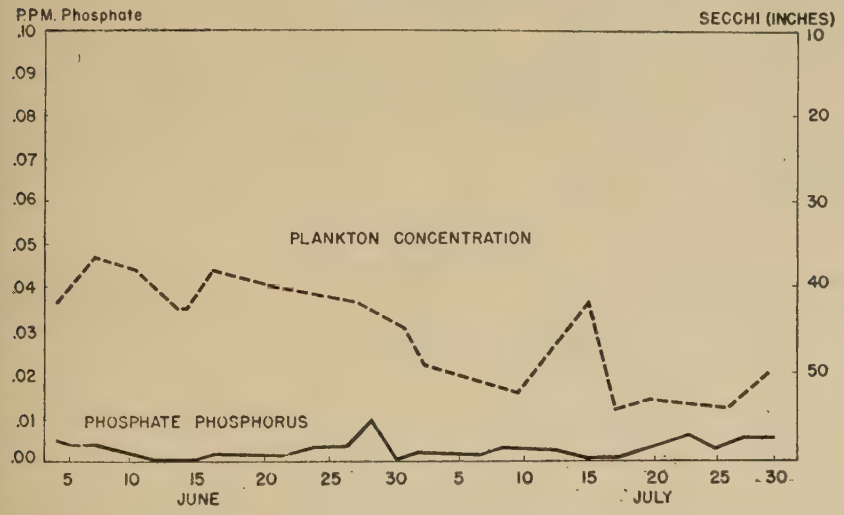

FIGURE 3.—Surface concentrations of phosphate phosphorus (p.p.m.; solid line) and plankton abundance in terms of light penetration (inches; broken line) in unfertilized Pond No. 6, summer of 1952.

and showed only minor fluctuations throughout the period of daily obsercation.

The nature of the fluctuations in the amount of phosphorus from day to day on both the surface and bottom of the ponds would indicate that some mechanism other than experimental error is involved in the changes encountered. The information obtained by the use of radioactive phosphorus by Hayes and Coffin (1951) suggests that these changes are due largely to a mobility of the phosphate ion. They reported movement in the hypolimnion of about 160 feet in a lateral direction and of not more than 12 feet in a vertical plane in a 2-week period. It is possible, therefore,

that in Missouri ponds a complete redistribution of phosphorus could occur in about 2 weeks. Since bottom concentrations remained at high levels, the process of sedimentation probably exceeds movement of materials from the lower stratum. These high bottom concentrations persist throughout the period of summer stratification. After the fall overturn, when fertilization has been discontinued, rapid increases of phosphorus are found for a short period of time. These concentrations do not persist, however, and by spring the phosphorus concentrations are similar in fertilized and unfertilized ponds and remain so until addition of fertilizer is renewed.

Conclusions

The results of this investigation suggest that fertilization of farm ponds would be improved by frequent application. Because of the low rate of solution, fertilizer applied at 1-week intervals in one-half the previous amount might be superior to the semi-monthly applications. The total amount of the fertilizer applied should remain unchanged, but it should result in a higher average level of phosphate in the pond water.

Where nitrogen concentrations are low, it would appear that a favorable nitrogen fertility might be maintained in farm ponds by the use of watershed plantings of legumes.

Literature Cited

Chu, S. P.
1943. The influence of the concentration of inorganic nitrogen and phosphate phosphorus (The influence of the mineral composition of the medium on the growth of planktonic algae. II). Jour. Ecol., Vol. 31, pp. 109–148.

Hayes, F. R., and C. C. Coffin
1951. Radioactive phosphorus and exchange of lake nutrients. Endeavour, Vol. 10, No. 38, pp. 78–81.

Ketchum, Bostwick H.
1939. The development and restoration of deficiencies in the phosphorus and nitrogen composition of unicellular plants. Jour. Cell. and Comp. Physiol., Vol. 13, pp. 373–381.

Rodhe, Wilhelm
1948. Environmental requirements of freshwater plankton algae. Symbolae Botanicae Upsalienses, Vol. 10, 149 pp.

Swingle, H. S.
1947. Experiments on pond fertilization. Ala. Poly. Inst., Agr. Exp. Sta., Bull. No. 264, 33 pp.

Part 11
Business Sessions

AMERICAN FISHERIES SOCIETY

Eighty-Second Annual Meeting

The eighty-second annual meeting of the Society was opened in the Baker Hotel, Dallas, Texas, at 9:30 A.M., Monday, September 8, 1952. The agenda were as follows:

Monday, September 8

Morning: Address by the President; roll call of members; action on nominations for membership; introduction of noteworthy guests and visitors; appointment of sessional committees; reports of officers, chairmen of regional divisions, standing committees, and *ad hoc* committee.

Afternoon: Presentation and discussion of papers.

Tuesday, September 9

Morning and Afternoon: Presentation and discussion of papers.

Evening: Reports of sessional committees; election of officers and committees; installation of the new President; concluding business.

Wednesday, September 10

Morning and Afternoon: Tour of local points of interest and barbecue.

Evening: Annual joint banquet—Crystal Ballroom, Baker Hotel.

REGISTERED MEMBERS IN ATTENDANCE

Aldrich, A. D., Okla.
Allison, Leonard N., Mich.
Allum, Marvin O., S. D.
Anderson, G. M., N. M.

Bagley, Lester, Wyo.
Bailliere, Lawrence, Mo.
Barker, Elliott S., N. M.
Barrett, Paul H., Mich.
Beckman, William C., Colo.
Bishop, Harry, Okla.
Bode, I. T., Mo.
Bonn, E. W., Texas
Brown, Maj. James, La.
Brown, William H., Texas
Burris, William E., Texas
Byrd, I. B., Ala.

Campbell, Robert S., Mo.
Caraway, Prentice A., Miss.
Carbine, William F., D. C.
Carlander, Kenneth D., Iowa
Clark, Minor E., Ky.
Cobb, Roland H., Maine
Cornell, James H., N. C.
Croker, Richard, Calif.
Cross, Frank B., Kan.

Davis, George, Vt.
Day, Albert M., D. C.
Degani, John G., Texas
Denmead, Talbott, Md.
Dequine, John F., Fla.
Elder, David E., Ill.
Elser, Harold J., Md.
Eschmeyer, Paul H., Mich.
Evans, Robert L., Colo.

Flury, Alvin G., Texas
Funk, John, Mo.
Faqua, Charles L., N. M.

Gerking, Shelby D., Ind.
Gordon, Seth, Calif.
Gottschalk, John S., Va.

Hall, Gordon E., Okla.
Hambric, Robert N., Okla.
Harkness, William J. K., Ont.
Harmic, Jay L., Del.
Harris, Charles H., Miss.
Hayford, Charles O., N. J.
Hazzard, Albert S., Mich.
Hess, Ray H., N. M.
Hildebrand, Henry H., Texas
Hile, Ralph, Mich.
Hill, W. C., Okla.
Hogan, Joseph R., Ark.
Hubbs, Clark, Texas
Hudoba, Michael, D. C.
Huish, Melvin T., Fla.
Hulsey, Andrew H., Ark.
Hunt, Burton P., Fla.

Illk, Paul J., Texas
Irwin, William H., Okla.

Jackson, Samuel W., Okla.
Janzen, Daniel H., Minn.
Jenkins, Robert M., Okla.
Joeris, Leonard, Wis.
Johnson, Raymond E., Minn.
Joslin, Vern E., Minn.

King, John, Okla.
Knapp, Frank T., Texas
Kolmer, Harold S., Md.
Kuehne, Robert A., Texas

Lamb, Leonard D., Texas
Langlois, T. H., Ohio
Lawrence, W. Mason, N. Y.
Leitritz, Earl, Calif.

Leonard, Edgar M., Okla.
Lewis, Leo D., Texas
Lewis, William, Sr., Ill.
Luethy, Don R., Fla.

MacKay, H. H., Ont.
Martin, J. Mayo, Okla.
McConnell, C. R., N. M.
Meehean, O. Lloyd, D. C.
Menzel, R. Winston, Texas
Moffett, James W., Mich.
Moody, Tom., N. M.
Morgan, H. R., N. D.
Morrison, Kenneth W., Texas
Moyle, John B., Minn.
Mullan, James W., Mass.

Parr, Sam A., Ill.
Patriarche, Mercer, Mo.
Pautzke, Clarence F., Wash.
Pillow, Braden, Okla.
Prewitt, Roy, Ark.

Reid, Cecil W., Texas
Roberts, Travis S., Miss.
Rubin, Mrs. Nell R., Ill.
Ruhr, Clifford E., Tenn.
Rutherford, Robert M., D. C.

Saila, Saul B., Ind.
Schafer, Harry E., Jr., La.
Schneberger, Edward, Wis.
Schoonover, Roy E., Kan.
Scott, Melvin O., Ind.
Seaman, E. A., W. Va.
Shoemaker, Carl D., D. C.
Sims, Fletcher, Jr., Texas
Smith, Spencer H., Miss.
Sneed, Kermit E., Okla.
Solman, Victor S. F., Ont.
Speaker, E. B., Iowa
Sprecher, George E., Wis.
Stevenson, James H., Ark.
Strawn, Kirk, Texas
Swenson, Hjalmar, Minn.
Swift, Ernest, Wis.
Swingle, H. S., Ala.

Tarzwell, Clarence M., Ohio
Thompson, Fred A., N. M.
Thompson, William H., Okla.
Thorpe, Lyle M., Conn.
Toole, Marion, Texas

Vibert, Richard, France
Viosca, Percy, Jr., La.

Wade, Gerry, Maine
Wagner, Richard A., Ariz.
Wallen, Irvin E., Okla.
Ward, H. C., Okla.
Washburn, George N., Mo.
Way, Seth L., Kan.
Werner, Walter H. R., Ont.
Whitaker, R. S., Ark.
Witt, Arthur, Jr., Mo.

Yoder, A. W., Ariz.

Zeller, Howard D., Mo.

OPENING REMARKS OF THE PRESIDENT

W. J. K. Harkness

In the early meetings of the Society—toward the end of the last century—much time was given to discussion of fish hatchery procedures. At the turn of the century and for a few years following, the emphasis was turned to consideration of the best use of hatchery products. Since then there has been a continuously accelerating tempo in other phases of fish management which has been accompanied by an encouraging interest in and development of research.

At the present time we note a major emphasis on management and a static or decreasing attention to hatcheries, with research holding no readily definable position. Public opinion is exerting great pressure in favor of general management activity. Our personal emotions are no brake to this either. If we can pull off a management scheme, we want to do so to show that we can and are rather proud of it, and we let ourselves go all out on management. Our common sense and scientific training should be a brake to letting this go too far.

Major emphasis on general management programs without adequate accompanying fact-finding research will cause as much grief, and will lead us into as non-productive a condition, as the general hatchery program did 50 years ago. Any management program, including assimilation of hatchery work, will succeed only when factual information resulting from research is available.

Above all else, research demands our first attention. After that we can deal with the subsequent stages in fish culture programs, application of results from research to management, training of men for management in the light of research information, and education of the public as to the facts available from research.

I do not wish to be misunderstood. I am not objecting to fisheries management. I think it is fine, in fact wonderful, and can in itself be a most useful big scale research tool when properly handled. What I do fear is the complacent attitude that accompanies an active management plan, and the training of fish management men on the basis of half truths and half baked ideas.

Fellow members of the American Fisheries Society, let us face the facts. In fisheries management we don't know where we are going. Furthermore, we haven't any idea. The sad, or perhaps the happy feature about it is that we *can* know, at least we can learn more than we know now, and that through research only. I wish to emphasize that without a strong research program we can and shall go nowhere. Sponsorship of such a program is the major responsibility of the American Fisheries Society membership if we are to accept the responsibility inherent in the tacit claim that we are the leaders in this field.

In conclusion, I wish to give you three references in which this need is

driven home clearly and briefly. Hoyes Lloyd, in his summarization of the Fifteenth North American Wildlife Conference at San Francisco, California, March 9, 1950, said. "The [Wildlife Management] Institute has said that the summary would be discussed under the general theme, 'Are We Wrong About Conservation?' The answer must be yes and no. We are wrong in many of the lesser things without question, because of our ignorance of the very complicated problems with which we deal. As new facts are learned, our errors can be lessened if the new ideas are applied. If they are not applied, we continue in error. This lag between discovery and application is not peculiar to wildlife; it affects many in many other ways. The old worn path of habit is easier than the new. We may still be wrong about some of the greater problems and yet, the effort is being made, has been made for many years, at these meetings and elsewhere, to learn the truth, tell the public about it, and then try to apply the truth through the usual administrative channels for the general benefit of all."

The second reference is to a paper by Dr. C. H. D. Clarke on research—"Research—Its Place in Conservation"—given at the Midwest Game and Fish Commissioners meeting at Des Moines, Iowa, on August 15, 1952, and, again, I am going to quote a paragraph: "There is one answer—research is, or should be, the careful and critical search for facts, and appraisals of assertions, whether newly put forth or accepted for centuries. This is a composite definition, but it contains as much as the authorities on our language will allow.

"Obviously research is basic to conservation, for how can we use resources wisely unless we have facts to go on, or in plainer words, unless we know what we are doing? Surely we have had enough of administration, which as A. L. Pritchard points out, is a word synonymous with management, based on premises uncritically accepted."

The third reference is from a paper written by Dr. Justin W. Leonard presented to the Michigan United Conservation Clubs last July, and I haven't any quotation from that paper here with me, but it is well worth looking over, beause it puts forth very forcefully the same truth.

Please think over some of the remarks I have made, because they illustrate the value of research, and the value of not stopping research to set up a management program simply because we have what we think solves one problem. What is the wisdom of using incomplete or inadequate information as basic facts in the teaching of management to persons who are learning these things as facts when actually they are half truths or less.

Fellow members of the Society, we have a very serious responsibility in the program of fish culture in North America, and I think the only answer to it is that we absolutely must insist on the support and development of research in every state and province by every appropriate federal agency and by universities and colleges, because without the facts we can neither carry out our management responsibilities nor can we hope to set up training schools for the training of men to do management work.

APPOINTMENT OF SESSIONAL COMMITTEES

Nominating

Albert S. Hazzard, Michigan, *Chairman*
Seth Gordon, California
Joseph R. Hogan, Arkansas
Milton C. James, Washington
H. H. MacKay, Ontario

Resolutions

H. S. Swingle, Alabama, *Chairman*
Raymond E. Johnson, Minnesota
William M. Lawrence, New York
Paul R. Needham, California
E. A. Seaman, West Virginia

Auditing

Leonard S. Joeris, Wisconsin, *Chairman*
Clark Hubbs, Texas
H. H. MacKay, Ontario

Time and Place

Richard Croker, California, *Chairman*
John F. Dequine, Florida
Clarence F. Pautzke, Washington
Lee S. Roach, Ohio
Edward Schneberger, Wisconsin

Publicity

Cecil W. Reed, Texas, *Chairman*
William H. Brown, Texas
Clark Hubbs, Texas

REPORTS OF OFFICERS

REPORT OF SECRETARY-TREASURER

GEORGE E. SPRECHER

When an organization is in serious financial difficulty or when severe administrative problems indicate a decline in the effectiveness of a group such as the American Fisheries Society, it is usually deemed advisable for the officers to present long drawn-out reports. Such reports attempt to sugar-coat the real facts and send the members home with a lot of hope but very little substance. My report will, therefore, be quite brief.

Your Membership Committee has accomplished the task of raising the total membership of the Society to the unprecedented high of 1,469 members.

Two divisions are now properly constituted as parts of this Society.

The Transactions are being published regularly and on time.

The membership rolls are kept active and are cleared on non-dues paying members annually.

The Librarian provides an accurate record of publications on hand and submits monthly remittances covering sales made.

A Nominating Committee was appointed in June to study the qualifications of individuals who will be asked to serve as officers and committee members of this Society.

The financial condition of the Society is excellent as shown by the following financial report:

July 1, 1951—June 30, 1952

GENERAL FUND

Balance on hand, July 1951			$ 5,732.65
Receipts:			
Annual Dues			
Individuals			
For the year 1947–48	$	3.00	
1948–49		3.00	
1949–50		121.00	
1950–51		387.00	
1951–52		4,727.00	
1952–53		75.43	$ 5,316.43
State Memberships			
For the year 1949–50	$	40.00	
1950–51		120.00	
1951–52		1,380.00	$ 1,540.00

Library Memberships		
For the year 1950–51	$ 8.00	
1951–52	288.00	
1952–53	16.00	$ 312.00
Club Memberships		
For the year 1951–52	$ 175.00	
1952–53	10.00	$ 185.00
Sale of Transactions and Special Publications		$ 1,221.10
Sale of Index		2.75
Miscellaneous		4.50
Total Receipts		$ 8,581.78
Total Receipts, plus July 1 balance		$14,314.43

Disbursements:

Printing of Transactions	$ 4,953.52	
Other printing	486.96	
Clerical services—Ann L. Zweck	99.49	
Postage and supplies	251.04	
Editing	33.64	
Reporting services	116.46	
Insurance	69.36	
Fidelity bond	18.75	
Travel expenses—Lloyd L. Smith, Jr.	106.50	
Index preparation	100.00	
Display poster	20.00	
Purchase of transactions	64.28	
Refund of annual dues	4.50	
Miscellaneous	10.70	
Total Disbursements		$ 6,335.20
Gross Balance, General Fund, June 30, 1952		$ 7,979.23
Bank debit memos, etc.		6.76
Net Balance, General Fund, June 30, 1952		$ 7,972.47

PERMANENT FUND

Balance on hand, July 1		$ 2,206.37

Receipts:

Individual Life Memberships	$ 300.00	
Dividend Income		
Consumers Power Company	56.00	
Central Illinois Light Company	13.20	
Mortgage Certificates		
Principal Distribution	65.00	
Total Receipts		$ 434.20
Total Receipts, plus July 1 balance		$ 2,640.57

Disbursements:

Refund of Life Membership	$ 33.00	
Purchase of government savings bonds	2,220.00	
Total Disbursements		$ 2,253.00
Net Cash Balance, Permanent Fund, June 30, 1952		$ 387.57

RECAPITULATION

Net Cash Balance, June 30, General Fund	$ 7,972.47
Net Cash Balance, June 30, Permanent Fund	387.57
Net Cash Balance, June 30, both funds	$ 8,360.04

SECURITIES HELD, JUNE 30, 1952

(1) New York Title and Mortgage Company, Series F-1		
Certificate No. 10811		Paid in full
(2) Title Guarantee and Trust Company		
Certificate No. 103553		Paid in full
Certificate No. B-71070		
(3) U. S. Government Savings Bonds		
No. D682395F 8-29-49 ($500 mature value)	$ 390.00	
No. M1610061F 8-29-49 ($1,000 mature value)	780.00	
No. D702345F 12-15-50 ($500 mature value)	380.00	
No. M1703542F 12-15-50 ($1,000 mature value)	760.00	
No. M1703542F 12-15-50 ($1,000 mature value)	750.00	
No. M1773329F 10-31-51 ($1,000 mature value)	750.00	
No. M1773330F 10-31-51 ($1,000 mature value)	750.00	
		$4,560.00
(4) Consumers Power Company		
No. G-6085, 28 shares at 35 5/8		$ 997.50
(5) Central Illinois Light Company		
No. B-1752, 6 shares at 37		222.00
Total		$ 5,779.50

Since July 1, 1952, $4,866.41 has been deposited to our account in the bank. As of August 31, 1952, our bank balance shows a total of $13,123.29.

I now recommend that the $5,500 which was transferred from the permanent fund to the general fund in 1949 be returned to the permanent fund at this time.

A proposed budget for the 1952–53 fiscal year is submitted herewith.

PROPOSED BUDGET—1952–1953

General Fund

Balance on hand, June 30, 1952		$ 7,972.47
Estimated Receipts		
1,280 Active Members at $4.50	$ 5,760.00	
84 Library Members at $4.00	336.00	
36 Official Members at $40.00	1,440.00	
20 Sustaining Members at $10.00	200.00	
Sale of Publications	1,500.00	
Total Estimated Receipts		9,236.00
Net Estimated Income		$17,208.47
Estimated Disbursements:		
Repay Permanent Fund	$ 5,500.00	
Printing—Volume 81	4,500.00	
Other Printing	500.00	
Postage	300.00	
Editing	150.00	
Stationery and Supplies	200.00	
Reporting Services	150.00	
Clerical Services	200.00	
Travel Expenses	250.00	
Fidelity Bond	18.75	
Fire Insurance	70.00	
Miscellaneous	100.00	
Total Estimated Disbursements		$11,938.75
Estimated net balance, General Fund, June 30, 1953		$ 5,269.72

In conclusion, I would like to express my appreciation for the excellent cooperation furnished me by the President, Vice-Presidents, Librarian, and other members of the Executive Committee and the members of the Society. I would also like to call your attention to the new certificates which are now available to Honorary and Life Members of the Society.

REPORT OF THE LIBRARIAN

William C. Beckman

Since last reporting to the Society from August 17, 1951 to August 20, 1952, 482 copies of the Transactions, 35 indexes, and 120 copies of "A List of Common and Scientific Names of the Better Known Fishes of the United States and Canada," were sold. An inventory was taken on August 20, 1952, at which time 3,812 Transactions, 451 clothbound indexes, 129 paperbound indexes, 1162 Special Publication Number 1 and 990 Constitution and By-Laws were on hand.

During the year, in response to the request of the Librarian in the Newsletter, several individuals sent in duplicate copies they had in their possession. Some of these were exchanged for other volumes or bought. All such volumes were sold to libraries to fill in their sets.

The money received from the sale of the volumes was turned over to the Secretary-Treasurer each month. He has reported the amounts received.

I must again report to you that work on the accumulative index is still in progress. There is going to be one difference in the report from last year. I am not going to tell you when it is going to be done, because I don't know. It has taken a lot longer than I thought it would. I have nine more volumes to go, and I estimate now it will require the preparation of between twenty-five and thirty-five thousand three by five reference cards. So, I will try to get that out to you next year. However, I do not promise that I will.

REPORT OF THE CHAIRMAN OF THE NORTHEASTERN DIVISION

Gordon L. Trembley [1]

We had a very fine meeting as far as attendance was concerned. In fact, we had more people than we thought we could accommodate but we stacked them in somehow. There are no formal accommodations in Jackson's Mill, West Virginia. Jackson's Mill is the largest 4-H Camp of its type in the country. It is a very informal type set-up and camp. All sessions were informal, and everybody had the privilege of saying anything he wished in the discussions. The meetings were centered around a discussion basis on the panel type, just a few papers on the formal side. We felt that the representation of 21 States and Provinces was very good for the Northeastern Division. The organization of the Northeastern Division was completed, and that will be reported on, I presume, later on in the meeting. I can't think of anything else that might be mentioned except that we are very proud of our Northeastern Division. We have a real set-up with Gordon L. Trembley the new Chairman, and I feel con-

[1] In the absence of the Chairman, his report was presented by Elwood A. Seaman.

fident that when we meet this fall in New Hampshire, sometime in the fall of 1953, that we will have a very fine and well organized Northeastern Division.

REPORT OF THE CHAIRMAN OF THE WESTERN DIVISION

Clarence F. Pautzke

Our Western Division meeting went off in good style this year. The infant division of the American Fisheries Society with 11 western states held its meeting at Glacier Park, Montana. The enthusiasm and the attendance was of the highest degree. We had an attendance at Glacier Park of better than 100 members with a full catalog of papers. The problems of the 11 western states compare with all the other sections of the United States except perhaps as regards intensity of fishing. We do not feel that our fishing intensity has reached the scope that is found in the East. At this Western Division meeting our most important problems seemed to be the development of new waters, public access, and the buildup and maintenance of our native species of fish.

The Western Division was under the Presidency of Mr. Yoder during this past year, and he did a very fine job of spearheading the activities of that Division. This coming year our meeting will be held some place in California, and we expect a sizable increase in the number in attendance. Fisheries research on the Pacific Coast and in the Western States is progressing very rapidly, and we are proud to be associated as a division of the American Fisheries Society.

REPORTS OF STANDING COMMITTEES

COMMITTEE ON INTERNATIONAL RELATIONS

W. C. Senning [1]

During the past year several events of International importance have taken place. Perhaps one of the most far-reaching significance is the convention for the Fisheries of the Northwestern Atlantic in which approximately 12 nations have gotten together to try to conserve and manage fisheries resources, roughly beween Iceland and Greenland. This Commission had its first formal meeting during the past year and is busy now drawing up regulations to govern the activities of the fishermen from many nations.

On the other side of the continent a tripartite committee was signed and ratified all during the past year. This was the first treaty engaged in by Japan since the peace treaty. I think this treaty will go a long ways too in developing a method for bringing nations together to conserve and regulate their fisheries and to keep them from being overfished by people from other countries.

Of course, it is needless to report anything on the halibut and salmon treaty which are taken pretty much for granted now. They go on from year to year without any particular commitment. The Inter-American Tropical Tuna Commission between Costa Rica and the United States is still flourishing except that the United States Government has not appropriated enough money to carry on as it should. However, the research staff is working the best they can and have established a headquarters in San Diego, California, and a branch research station particularly for the study of the bait fish for tuna at Costa Rica.

Just last month the governments of Ecquador, Peru, and Chile negotated a fisheries treaty, and under its terms apparently these three countries will renounce some of their national rights to a three-party commission to regulate and conserve their fisheries which is of mutual concern. Those, I believe, are the principal highlights. Perhaps some mention should be made of the association which is composed of businessmen of Mexico and the Gulf States. This association is trying to work out the problem of imports of shrimp and depredations of American boats in alleged Mexican waters. Government negotiation has not been too successful. Apparently, these businessmen and fishermen are finding it possible to settle their problems without Governmental intervention, you might say. Those are the principal highlights with which I am familiar, and I am sorry the committee chairman wasn't able to be here.

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1 In the absence of the Chairman, this report was presented by Richard Croker, member of the Committee.

COMMITTEE ON NATIONAL-STATE RELATIONS

WAYNE D. HEYDECKER [1]

Cooperation in the administration of fish conservation programs in America has become such a common phenomenon that it is taken for granted as an essential component of the modern way of getting things done. There remain, inevitably, situations where the degree of cooperation, and hence the status of relations, is still somewhat short of the most desirable. Nevertheless, relations between the state and federal agencies have undergone steady improvement. The cooperative policies of the various federal agencies, the organization of three powerful interstate fishery commissions in the Atlantic, Gulf, and Pacific coasts, and general interest on the part of states individually to strengthen their programs through cooperative efforts, have all contributed materially to the effectiveness of federal-state teamwork.

This report presents a condensed review of several of the more important cooperative activities currently in progress in the United States, and highlights significant developments of the past year. There are doubtless many examples of worthwhile cooperation, and others which indicate the lack of it, of which your Committee is not aware. The contributions to the committee by members and by the federal agencies is gratefully acknowledged.

RELATIONS BETWEEN THE STATES AND THE U. S. FISH AND WILDLIFE SERVICE

The Federal Aid in Fish Restoration Program, made possible by the approval of the Dingell-Johnson Act on August 9, 1950, went into operation on July 1, 1951. Funds available for apportionment to the states for approved investigations and developments totalled $2,574,910.71 during the first year. Of this amount, the states had obligated $1,499,863.26 by June 30, 1952, in 154 projects, 112 of which were in actual operation. Ninety-four of the 154 projects consisted of investigations of various fish-management problems. Development projects, ranging from watershed improvement to the construction of fishing lakes, totalled 21. Four projects were in operation for the purchase of lands or water areas to be used for future lake construction, as public fishing access sites, or for protection of fish habitat. Coordination projects, which are designed to provide overall supervision and direction for activities financed by federal funds were put in operation by 35 of the states. Alaska, Hawaii, Puerto Rico, and the Virgin Islands also began work on fishery problems with funds made available by the Dingell-Johnson Act.

Previously established functions of the Fish and Wildlife Service in the fishery field continue to emphasize the cooperative approach. The shad-

[1] All but the concluding portion of this report is the work of John S. Gottschalk who later succeeded me as Chairman of this Committee. I wish to express to him the appreciation of the Committee members for his painstaking research and his excellent summarization of a broad field.

producing states of the Atlantic seaboard and the Service are cooperating in an investigation of the Atlantic shad, the work being concentrated this year on Chesapeake Bay. A cooperative water-quality study on the Hudson was completed in the summer of 1951. Conclusions are that the pollution load has increased considerably since 1936 and is at a point where it may seriously affect shad production. Means of rehabilitating the sea-run salmon in Maine is the object of another project, while in the four southern states on the Atlantic coast a joint shrimp program is under way. A proposed joint program for research on striped bass was outlined during the year. At the request of the Gulf States Marine Fisheries Commission, the Service is investigating several aspects of the fisheries of the Gulf.

On the Pacific coast, cooperative projects are under way to investigate the effects of irrigation on salmon in the upper Sacramento River and to study the Pacific sardine which once topped the production of any of the nation's fishes. Through the Colorado Cooperative Fishery Research Unit, an inventory is being made of the biological, physical, and chemical characteristics of reservoirs with fluctuating water levels so that management plans can be developed.

The Great Lakes have been our most valuable source of fresh-water commercial fishes until recent years. The sea lamprey has now become so abundant as to deplete seriously the stocks of fishes. Annual production of food at stake is 75 to 90 million pounds of commercial fish and an estimated 25 to 50 million pounds of sport fish. Preliminary figures show the 1951 production of lake trout in United States waters of Lake Huron to have been less than 100 pounds and indicate that in Lake Michigan, which yielded above 6 million pounds as recently as 1944, the 1951 harvest may have been less than 10,000 pounds. The Great Lakes Sea Lamprey Committee, consisting of representatives of all eight Great Lakes States, the Province of Ontario, and the U. S. Fish and Wildlife Service, has under way an intensive research program designed to develop methods for the control of the sea lamprey, and to restore the Great Lakes fishery stocks to their former economically profitable level of abundance. Preliminary experiments made with electrical devices in 1951 have demonstrated that all upstream migration of adult sea lamprey can be stopped.

Over a period of several years, the Fish and Wildlife Service has worked with the states to promote greater coordination of various fish-cultural and stocking practices. At present most of the states review applications for fish submitted through federal channels, prior to their approval by the Fish and Wildlife Service, to determine the propriety of stocking the waters specified with the species requested. Cooperative agreements have enabled a number of states and the Service to make full use of hatchery facilities and economize in the distribution of fish. As an aid in the accomplishment of these objectives, additional emphasis is being placed on the solution of fish-management problems in cooperation with the states.

The past year has been marked by combined efforts of state conservation agencies and the Fish and Wildlife Service to preserve the important fishery

resources subject to potential damage by proposed water-development projects. In the Columbia River Basin, both the proposed Cowlitz Power Project on the Cowlitz River in Washington and the Pelton Power Project on the Deschutes River in Oregon were vigorously opposed by the state conservation agencies and by the Fish and Wildlife Service on the grounds of anticipated harm to fishery resources. A third power project, Rock Island Dam, is being altered to provide expanded power production. The Fish and Wildlife Service and the State of Washington have worked closely throughout the year to supply information on modifications of the fish-passage facilities necessitated by the proposed changes in project facilities and operation.

The Secretary of the Interior, in his letter of March 21, 1952, to the Federal Power Commission supported the joint position of the Fish and Wildlife Service and the Wisconsin Conservation Department by opposing a proposed hydroelectric power development on the Namekagon River in Wisconsin. This project would destroy a section of whitewater stream highly prized for its excellent smallmouth bass float-fishing.

The recent publication of the Conservation Commission of West Virginia, "Bluestone Reservoir Survey", presents the results of cooperative studies on Bluestone Reservoir in West Virginia.

In the field of commercial fisheries, a number of other cooperative endeavors are under way. These projects include work with the Atlantic States Marine Fisheries Commission to determine the effect of industrial wastes on marine fisheries and a program of exploration, technological, and statistical research. A similar research operation is being carried on with the Gulf States Marine Fisheries Commission. Cooperative programs for the collection and compilation of fishery statistical data are in effect with the Maine Department of Sea and Shore Fisheries, the New Jersey Department of Conservation and Economic Development, the Texas Game and Fish Commission, the University of Delaware, and the University of Miami.

Relations between the States and the U. S. Bureau of Land Management

In the past 15 months pilot soil-conservation districts have been established in several of the western "public domain" states to develop a pattern of cooperative conservation and resource utilization to which all affected land-management agencies and private land owners can subscribe. Full consideration is given to the present and potential fishery resource of the district in planning for the conservation and utilization of the available water supply. Excellent opportunities for cooperative effort in fishery protection and development lie in the revested forest lands located in western Oregon. As a protective measure, strips of these lands bordering fishing streams are designated and no activities detrimental to fish populations are permitted within the specified strips. In many situations, "timber

reservation strips" are made. In other instances where some logging is permitted, the operator is required to clean out any debris which may accumulate in any stream. These activities are planned and conducted by the Bureau of Land Management with the cooperation of the Oregon State Game Commission. Other cooperative activities included assistance to the Idaho Game and Fish Department in salvaging a large number of trout in several major irrigation canals that flow through the grazing lands of the Wood River grazing district, and assisting similarly in Wyoming, Montana, and Idaho. Small reservoirs constructed under the Bureau's soil and moisture conservation program in Montana have been stocked with fish supplied by state hatcheries.

Relations between the States and the U. S. Bureau of Reclamation

For the past several years the Bureau of Reclamation has endeavored to transfer to appropriate state agencies jurisdiction over the administration of fish and wildlife conservation activities, recreation, and other public uses on Bureau of Reclamation reservoirs. During the past year positive advances have been made in this direction; transfer has been made on 12 reservoirs in seven western states.

During this past year, also, the Bureau has compiled and published a report on recreational use and fish and wildlife conservation advantages resulting from the construction and operation of reclamation reservoirs throughout the 17 western states. Copies of this report entitled "Reclamation Pays an Extra Dividend in Recreation and Conservation," are available to interested individuals.

Relations between the States and the U. S. Forest Service

In North Carolina the Forest Service entered into a cooperative agreement with the state and the Fish and Wildlife Service to study watershed-fishery environmental relationships at the Coweeta Hydrologic Laboratory. The importance of additional knowledge on this subject has been recognized by fishery managers for many years. To date few determinations have been made of the degree to which various watershed-influencing factors affect fish habitat. In Montana a similar cooperative study was undertaken to determine the characteristics of trout populations on a watershed prior to logging. The effects of logging on trout populations will be determined by later population studies after the watershed has been cut over in accordance with accepted silvicultural standards.

Of special importance in the cooperative fishery management field is the expansion of the program in West Virginia which will be made possible by a new national forest fishing stamp. New state legislation requires each fisherman using national forest waters to purchase a $1 stamp. The additional funds made available have already stimulated the fish-management program. In Kentucky the Forest Service cooperated with the state in

making preliminary plans for recreational developments on newly created Cumberland Lake. These developments will be used primarily by fishermen and will contribute materially to increased sport fishing and proper harvest of the fish population. A cooperative study by the Forest Service and the Utah Fish and Game Department has been initiated on Fish Lake to determine ways of stabilizing the level. Fish Lake is one of the most productive bodies of water in Utah, but present draw-down for irrigation purposes materially reduces the food-producing and spawning areas around the shoreline.

A recent example of progress in a continuing program is the development of means for the control of removal of legal-sized hatchery-reared trout on Barbours Creek on the Jefferson National Forest in Virginia. Here, on a cooperative demonstration area where alternate closed sections of stream are stocked, it has been shown that under this procedure the fish are removed over a longer period of time and better recreational sport has been provided.

Relations between the States and the U. S. Corps of Engineers

The Corps of Engineers recognizes the responsibilities of the states for matters pertaining to the management and control of fish in impounded waters under its jurisdiction and cooperates fully with the responsible state agencies in their fishery programs in such waters. Accordingly, National-State relationships in this field are predicated upon the control and management of the fishery by the state and planning, construction, operation, and administration of each project by the Corps of Engineers in such manner that maximum public benefits consistent with the purposes of the project may be obtained from its natural resources. The magnitude of public benefits from fishery resources created by reservoirs constructed by the Corps of Engineers for flood control, navigation, power, water supply, and related purposes, is becoming more apparent each year. Seventy-five of these reservoirs provided over 6,350,000 man-days fishing and 8,400,000 pounds of sport-fish harvest in 1951, which is reflected in business returns by expenditures estimated at between $30 million and $50 million by the fishermen. More than 24 million pounds of fish were harvested from Corps of Engineers' project areas during the year.

The Corps of Engineers solicits the cooperation and assistance of all interested conservation agencies in joint planning for administration of its projects. For example, the creation of new bodies of impounded water leads to popular interest in stocking fish with resulting requests to the states for new fish hatcheries to provide the planting stock. Since states are usually budgeted to the full extent of their available funds for their fish-hatchery programs, proposals are then made that fish hatcheries be constructed at federal expense as an integral part of reservoir projects. Situations of this type obviously call for further study and consideration of the needs for fish stocking, the nature of benefits that may be derived, and

the responsibilities of the respective agencies for state and federal programs for fish management.

Federal-State Relations in Pollution Control

Since the initial appropriation of funds in fiscal year 1950 under provisions of Public Law 845 (Water Pollution Control Act), the Division of Water Pollution Control of the U. S. Public Health Service, Federal Security Agency, has worked closely with state and interstate agencies on abatement activities. Inherent in such activities is the development of comprehensive programs, giving due regard "to the improvements which are necessary to conserve such waters for public water supplies, propagation of fish and aquatic life, recreational purposes, and agricultural, industrial, and other legitimate uses." [2] It is necessary, therefore, that there be cooperative working relations between the Federal government and those State agencies having responsibilities and interests in these uses of water.

Where fishery resources are involved, the avenue of cooperative relations with the appropriate State agency in pollution control is essentially one of the following: (1) in 22 States the official water pollution control agency is a board or commission having direct representation by the State fishery agency or agencies; [3] (2) in 22 States the health authority is the official water pollution control agency in which case there usually are informal working relations with the fishery agency; and (3) in four States, where the agency is a board, representation is not designated by statute. In addition, the fishery agencies of 15 States have certain authority over water pollution specifically affecting aquatic life. These arrangements provide the basis for cooperative actions either directly or indirectly with state fishery agencies on matters involving fishery resources and water pollution.

Phases of the nation wide pollution control effort that have a bearing upon the welfare of fishery resources fall into two principal categories. The first is related to the fact that widespread efforts aimed at abating pollution are frequently beneficial to the fishery through habitat improvement regardless of the principal motivating factors and other benefits that may result. The second includes cooperative efforts on specific problems in which the principal pollution damage is to the fishery. These two categories are summarized below.

Early in the first phase, it was necessary to gather from various agencies available facts showing the present pollution problem in the nation. Cardinal points are: uses of water resources; suitability for such uses; impairments caused by pollution; origin and kind of polluting agent; and necessary remedial measures. Such information has been analyzed and incorporated into 15 documents covering 226 river basins in the country and also summarized in a national report. Separate river basins have since

2 Quoted from Public Law 845.
3 Some of these are administered within the State Health Department.

been taken as working units for the development of comprehensive abatement programs. Through cooperative actions with State and interstate agencies, investigations have been completed on 81 river basins. These studies provide the factual background for a plan designating the corrective actions to be taken by each municipality and each industry to make the waters suitable for desirable water uses.

Since it is ultimately the people who will support the program and pay the bill, the facts and the plans for corrective actions are being brought to them through a series of digests of the technical reports and through other media for spreading information. Enactment of adequate state laws has been encouraged. A suggested Water Pollution Act has been developed which calls for an administrative or advisory structure giving full representation to the state fishery agency or fishery interest. Eighteen states have thus far utilized the principles of the model Act in attempting to make legislative improvements. To date 11 States have been successful in obtaining such improvements.

During fiscal years 1950–1952, grants were made to state and interstate agencies for conducting studies and investigations related to pollution caused by industrial wastes. More than 263 major stream surveys were carried out by the states during the first two years, and 3,070 industrial pollution problems were investigated. About 15 percent of the grant funds have been used for research on industrial waste problems of regional or national importance. Practically all activity has been marked by consultation and close working relations with the agencies and groups whose responsibilities and interests lie with the various ways in which water has use and value. Noteworthy is the Water Pollution Control Advisory Board, charged with the duty of reviewing the policy and program of the Division. Its representatives include members from the Department of the Interior (presently an employee of the Fish and Wildlife Service) and the field of wildlife conservation (presently an officer of the National Wildlife Federation).

Funds have been granted to the Atlantic States, Gulf States, and Pacific Marine Fisheries Commissions for investigations relating directly to industrial pollution and fisheries. Federal funds have been used to support extensive toxicity bio-assay studies with fish and industrial wastes undertaken jointly by the Washington Pollution Control Commission and the State Department of Fisheries. Other states also, such as Pennsylvania, have utilized grant funds for toxicity studies with aquatic organisms.

Assistance has been given to the states through some 40 water pollution surveys in which fish were a prime consideration. Frequently the state fishery agency has been a direct field participant, as on the Mississippi River at St. Louis where the flesh of fish was being tainted, or on the Clearwater River in Idaho where the effects of new pulp-mill pollution upon salmon and steelhead trout are under study. As occasion arose, technical assistance was given in connection with fish kills such as those caused by insecticides in Alabama and by other causes elsewhere.

Financial support has been given to three field research projects directed toward protection of fish and aquatic life. Effort is directed in Oklahoma, for example, to determining tolerable discharges of oil-field wastes, and in Florida of specific particulate wastes. A study on the Willamette River in Oregon follows biological changes as an abatement program progresses.

State water pollution control agencies have been encouraged to place greater emphasis upon biological relations in the entire field of water pollution. The number of aquatic biologists in such agencies has increased from 2 to 22 since 1948, and 12 States have definite arrangements for such biological assistance from the fishery agency as pollution problems require.

The Environmental Health Center in Cincinnati, Ohio, serves as the research arm of the Public Health Service. Among the many water pollution and industrial waste research projects in progress there are the following in the Toxicity and Fisheries Unit of the Biology Section: (1) literature review on the toxicity of wastes to fish; (2) standardization of practical toxicity bio-assays with fish; and (3) development of toxicity bioassay methods. Results are made available, and industries and state agencies are encouraged to utilize these techniques in their programs.

In general, excellent cooperation has existed between the Public Health Service and water pollution control, fishery, and other agencies of the states. With the common cause of protection and rehabilitation of otherwise suitable fish habitats and prevention of outright killing of fish it is fitting that continued cooperation be nurtured and enhanced by even closer working relations than now exist.

Problems in Reservoir Management

The management of the fisheries and the wildlife resources of federally-constructed water impoundments continues to be an unsettled problem. One member of the committee suggests that the state conservation agency should be responsible for the management of fish and wildlife resources within any federal impoundment area, except for those areas which have primary value for migratory waterfowl. Where waterfowl values are paramount the Fish and Wildlife Service should manage the area, with state regulations applying to non-migratory species of wildlife and fish, provided that such State regulations would not permit public use of a nature detrimental to migratory wildlife conservation. Boating should be permitted where it will not conflict with other primary uses and should be regulated by the state under agreement with the operating agency. All areas of land in an impoundment area leased for agricultural uses should be subject to a stipulation providing for free public access for the purposes of hunting and fishing.

Legal Developments in Federal-State Relations

Four years ago when I had the honor of serving in this same capacity as Chairman of your Committee on National-State Relations, in my report

I offered for your consideration a review of the legal background affecting such relations in the field of conservation. (Transactions, Vol. 78, 232–237). Since that time, the Supreme Court has handed down two additional Tidelands decisions with respect to Texas and Louisiana but neither of them has served to alter the pattern with respect to marine fisheries, for the leading fishery cases cited in our report 4 years ago appear to have been distinguished and not overruled. Moreover, in the interim the Congress has given its consent to the Gulf States Marine Fisheries Compact, has consented to an amendment strengthening the Atlantic States Marine Fisheries Compact, and in the enabling legislation relating to the International Convention on the Northwest Atlantic Fisheries has retained clauses protecting the existing jurisdiction of the states.

From these events it seems clear that the Congress intends to preserve the fishery jurisdiction of the several states as an indispensable part of our governmental system.

However, there is pending in the House of Representatives a bill by Congressman Clemente, H. R. 8067, which would upset long established federal-state relations in the marine fishery field by overriding existing state laws in making it a federal offense to take striped bass except by hook and line, within the maritime and territorial jurisdiction of the United States under penalty of a fine of not less than $500 nor more than $1,000 or imprisonment for 60 days or both. This bill has been opposed vigorously by the Pacific Marine Fisheries Commission, by the California Department of Fish and Game, and by the Striped Bass Committee of the Atlantic States Marine Fisheries Commission. By the time this paper is presented to you, I anticipate that Commission will have endorsed the action of its Committee.[4]

There is no evidence of overall depletion of striped bass on the Atlantic Coast, nor so far as I know, on the Pacific Coast. On the contrary we read in current sportsmen's journals of large schools of large bass at many places along the Atlantic Coast and of evidence of many young bass. A carefully planned cooperative federal-state research program for striped bass is now under consideration by the states along the Atlantic Coast which are members of the Atlantic States Marine Fisheries Commission and which have the authority to act and have proven their readiness to act when necessary.[5] The States on the Pacific Coast in the Pacific Marine Fisheries Commission likewise have demonstrated their ability and readiness to adopt such conservation measures as they deem necessary.

The Clemente Bill, H. R. 8067, is ill-conceived, unnecessary, and unenforceable.[6] If adopted, it would strike a serious blow at the cordial federal-state relationships and at the effective cooperation which has been built up over the years. I hope that the members of the Society will concur in these views and record their objections to this proposed legislation with

4 It did so at its Eleventh Annual Meeting in Boston, September 3-7, 1952. Similar bills have since been introduced in the 83rd Congress and are similarly being opposed.

5 This cooperative program adopted at the Eleventh Annual Meeting of the Commission, September 3-7, 1952; supervisory personnel now employed (May 1953) by the U. S. Fish and Wildlife Service and commitments being made by states as rapidly as possible.

6 This is also true of H.R. 1990—83rd Congress, First Session, by Mr. Delaney, now (June 1953) pending before the same committee.

the House Committee on Merchant Marine and Fisheries, to which the bill has been referred.

Summary

In conclusion I wish to thank my colleagues on this Committee for their cooperation. I hope they will agree with me in saying that:

1. Federal-state fishery relations are improving steadily.

2. The cooperative policies of the U. S. Fish and Wildlife Service, and the organization of three powerful interstate fishery commissions on the Atlantic, Gulf, and Pacific Coasts have contributed greatly to that end.

3. Other agencies such as the U. S. Public Health Service and the various Bureaus of the Department of the Interior are providing increasing evidence of the effectiveness of federal-state team work in fields that affect the fisheries.

4. Recognition of such progress does not mean that the millenium is here, or that all selfish-interest groups or ambitious bureaucrats, whether in federal or state service, have suddenly been transformed into cooperative members of a "federal-state-public" team.

5. Still greater progress in federal-state-public relations lies ahead, when all of us, federal and state officials, scientists, administrators, and special-interest groups alike, remember that true conservation does not serve the selfish interests of some particular group or agency, but is designed to promote the wisest use of our natural resources for all the people and that we make the greatest gains when we work together.

EDITORIAL BOARD

Lloyd L. Smith, Jr.[1]

Since the last meeting of the Society, the Editorial Board has reviewed more than 50 papers which have been submitted for inclusion in the Transactions. Of this number 26 appear in Volume 81. This large number of manuscripts in addition to some factors beyond our control has delayed completion of Volume 81, but we can report that it is almost ready for mailing.

Three years of editorial work have emphasized certain aspects of the editor's job which cannot be known to those who have not assisted with the task. During the last year the Editorial Board has examined approximately 1,200 pages of copy, edited about half of this amount in detail, and made recommendations on the remainder. Each manuscript must be transmitted to associate editors and authors an average of four times with some manuscripts requiring as many as eight transmittals before page proof is ready. In addition to the work on manuscripts there is a large amount of clerical detail in handling and reading proof, contacting the printer, processing orders for reprints, and keeping track of art work. These activities add up to very large demands on the time and facilities of the committee and especially of the editor.

[1] In the absence of the Chairman, his report was presented by Raymond E. Johnson, member of the Board.

At the present time there is no prospect for a lightened load, but rather for an increase in the work. Formation of Regional Divisions has increased the number of papers which must be handled and the acceleration in scientific output will continue to make more papers available.

In view of the tasks which lie ahead it seems apparent that some changes in editorial management must be made to handle the increased flow of papers and at the same time to assure the Society that a high quality of workmanship will be maintained. Any editor of a scientific journal has a primary obligation to protect his readers from immature and improperly executed papers and to help maintain standards by preventing the inclusion of sloppy and insignificant work in the literature. To accomplish this end men capable of good editorial work who also have time to devote to it must be secured for the job.

In many societies including the American Fisheries Society it has been the practice for active workers in the field to undertake editorial work without compensation in addition to their regular duties. It is perhaps ironical but usually true that the same men who are most desirable as editors are also those who are the most active in research or administrative duties. Because editorial work is outside the regular functions of these men, it must of necessity take second place in their primary jobs. It is inevitable that delay will occur in many instances or that other duties must be neglected in favor of the editorial work.

Various societies have met this problem in different ways. The particular solution usually depends on the volume of editorial work and the financial status of the organization. Ideally, a full-time paid editor should guide the destiny of a scientific publication. However, the finances of many societies preclude this arrangement. A second alternative is to give a competent editor who is otherwise engaged in research or administrative activity a stipend which is sufficient to permit him to pay for some of the detail work that a good stenographer or assistant can accomplish satisfactorily. At the present time the financial status of the American Fisheries Society seems to make the latter alternative advisable.

Without some arrangement of this nature it will be impossible to secure and keep the services of the type of man required for the job. It is highly desirable that an editor stay on the job for as long a period as possible.

It is also recommended that the Editorial Board be reduced in number to three or four men who are capable and have the time to do detailed editorial work, and that a larger committee or group of referees for the appraisal of special papers be available to the editors for critical comment and suggestions on revision of content. With such changes in our editorial structure handling of the Transactions can be more prompt and the quality of the work can be maintained at a high level.

It is with regret that the Editor takes this opportunity to inform the Society of his resignation from the editorship. The work has been profitable and enjoyable to him and he is sure that the future of the Transactions will be placed in competent hands. He also believes that with some revisions of present policy perhaps along the lines suggested above greater continuity of editorial work can be attained.

COMMITTEE ON HYDROBIOLOGY AND FISH CULTURE

James W. Moffett

The fact that this committee was asked to prepare a report on research needs in fisheries, that the Wildlife Society has prepared a similar report for its field, and that many articles on the needs for research in other areas have appeared recently in several journals, is highly indicative of a widespread feeling of a basic weakness in the sciences. This atmosphere of unrest is certainly a mark of "growing pains" in scientific circles in America. Here is an indication of incipient maturity—a desire to move from the technological and developmental phase in American science to a more contemplative, deliberative stage. These signs are gratifying and offer a hope that production of new principles, new ideas, theories, and systems may become a more prominent attribute of American science.

Impediments to Effective Research

To a large degree the impediments to effective research have their roots in our very culture—a culture that confuses scientific engineering with true research, that deifies technological "know-how" but has little patience for the drab, tedious, long-term inquiries on which it is based. Horowitz [1] has described the present status of our culture so aptly that some of his remarks are quoted herewith:

> "We live in an atmosphere and within a system that value the football coach more than the scholar. . . . We lay more stress on doing, on importance of the *act,* and less on knowing. . . . We glory in our "know-how", in our mechanical ability, in overt accomplishment. And whether for good or evil, our educational institutions are turning out people, who, by training, *fit into* this cultural scheme. . . . Our theorists, thinkers and system builders are, for the most part, second-rate. . . . We place great value on memory, on facts, on knowledge for a purpose. And always with us is the emphasis on grades. We tend to stimulate learning not through intrinsic interest or desire for knowledge but through an external and irrelevant incentive. Try as I will, the image of the donkey with the carrot held just out of reach of it continually comes to mind.
>
> "The rigidity of the classroom, the compulsory attendance, the required courses, the omnipresent quiz and examination, all combine to stifle spontaneity and creativity and to drive the student along a prescribed path that someone else considers desirable. It is no etymological accident that students frequently refer to their college as the factory, for in many respects our educational system is of the assembly-line, canned variety."

If Horowitz' description of our research "climate" is correct, it appears difficult to find a place in fisheries for research in the sense of the following dictionary definition: "Studious inquiry or examination; specifically, and usually, critical and exhaustive investigation or experimentation having for its aim the discovery of new facts and their correct interpretation, the revision of accepted conclusions, theories, or laws, in the light of newly

[1] Horowitz M. W., 1952, Teaching, research and thinking. The Scientific Monthly, Vol. 74, pp. 332-337.

discovered facts, or the practical applications of such new or revised conclusions, etc.".

The difficulty in finding a place for research in fisheries lies in the attitudes of many groups—the general public, anglers, commercial fishermen, administrators, legislators, and fishery biologists themselves. These attitudes run the full gamut from frank disinterest to an overabiding faith in the wonders of science—faith that turns sour when the anticipated miracles do not come off. All of these groups share, even though to a varying degree, an impatience that can be satisfied only by immediate and categorial answers; all are intolerant of any long-term or "impractical" research; all must have action even though it be nothing more than a frantic and futile scurrying about. Let us now examine a little more closely this question of attitudes; through the examination we may find the way to escape from some of our difficulties.

The general public concept that scientists are magicians to whom nothing is impossible is especially influential in the establishment of research programs in fisheries. Many persons, including some fishery administrators, believe or have believed that all troubles in fisheries will disappear immediately when scientists are added to the staff. With this naïve faith, it is understandable that their enthusiasm should be transformed to resentment when the administrative miseries persist; that research as an activity should come into bad odor and scientists be regarded as impractical and curious "fiddlers" undeserving of support; that investigational programs should so often be rendered impotent by lack of support. Surely we need improved understanding by administrators of the true nature of research and by researchers of the urgency of administrative problems.

The administrator for his part should realize that no basis exists at all for the classification of research as "practical" or "academic". All research that contributes to our knowledge of the way fish live is practical; properly conducted inquiries, on the other hand, are academically sound whether or not they are designed to yield immediately useful results. The administrator must grasp further that it is no more possible in fishery science than in agriculture to plant today and harvest tomorrow. When he makes unreasonable demands for quick appraisals of complex problem situations and comprehensive management programs for waters barely seen, much less studied, he is forcing charlatanism on his staff and inviting discredit on himself.

Scientists, in their turn, should recognize that the last word need not be said in an inquiry before some use can be made of the results. An investigation that has been properly planned and intelligently executed almost certainly will yield instructive results during its progress. An alert and cooperative researcher will inform himself as to the pressures that bedevil his administrative superiors and will regularly make available to them any findings that may contribute toward the easing of their problems.

In short, we need administrators who grasp that scientific facts cannot be ordered up like groceries in a market, that the results from a truly

worthwhile research program can seldom be anticipated, much less stipulated and scheduled. We need just as badly scientists who can carry out basic inquiries and at the same time assist administrators in their problems without stooping to superficiality.

Another condition militating against research in fisheries arises from the tendency in some of our educational institutions to graduate persons as fishery experts and not as biologists. Furthermore, these persons are encouraged to do research even though they have received little training for the pursuit. Their training is for action rather than analysis. Yet a great many graduates want to do research in positions or in organizations not established or operated for the purposes. The result is a multiplication of disjointed, isolated efforts, generally misdirected, that yield very little except misunderstanding and ill-will toward research as an approach to fishery problems.

Actually, the research field in fisheries is overcrowded with persons busily engaged in data collecting, field work, and management plans. Analysis and mature consideration of materials and data never seem to receive the proper emphasis. Collections of data can, and very often do, become useless burdens if they are not subjected to the quiet, wholesome deliberation and logical analysis necessary to force them to yield the information they contain. Anyone can collect data. But the power of cold, unbiased analysis is possessed by few on our fishery research staffs, not because capabilities for such analysis are essentially inborn but rather because they are not taught, or better yet, instilled by contact and example.

In our general approach to a fishery problem we exhibit a passion for *doing,* for *physical activity* and a revulsion at the mental drudgery and physical inactivity that inevitably go with the analyses. As a result we accomplish little real research. All of us recall instances where support for a program was forthcoming as long as it was an *action* program. But as soon as deliberation and treatment of data required long hours of physical *inaction,* the data were left untouched, and the persons reassigned to another *action* program. The researcher had only his personal impressions to offer as the result of all the field work. These impressions were always qualified and nebulous. Under such circumstances, the administrator is forced to conclude that research is expensive, yields nothing but vague opinions and merits no further consideration as a part of his *action* program.

Without the experience of doing the mental tasks in research, whether it be in management or in the so-called basic investigations, few men will be capable as researchers; furthermore, many persons illadvisedly trained as or encouraged to become researchers will never qualify. Lindsay [2] recognized this fact in a similar discussion of research in the physical sciences: "Anyone who seriously believes that the insatiable curiosity about nature and the rigid mental self-discipline that are the character-

[2] Lindsay, R. B., 1952, The Survival of Physical Science, The Scientific Monthly, Vol. 74, pp. 139-144.

izing marks of the scientist will ever manifest themselves in more than a negligible percentage of the population has little regard for the teachings of history."

A researcher must be imbued with the spirit to adventure, the wit to question and the wisdom to accept and use.

Two additional evils operate against orderly progress in fishery research at the present time. One is the drain of trained, qualified and well established scientists from our colleges and universities into government-sponsored research projects. Obviously, this drain leaves something to be desired in our student-training programs. The other evil, which is gradually being eliminated, consists of requiring promising scientists to assume greater and greater burdens of administration as they progress up the pay scales of our various research institutions. Through this policy our best, most mature talent is lost to the very activity in which it showed aptitude. Administrative responsibility has smothered many scientific careers and dwarfed many programs by removing the very key men who had the attributes necessary for sound research. There is no profit in the policy which pays salaries according to relative position on the organizational chart and gives no proper compensation for talent and ability.

Recommendations for the Improvement of Research

In our comments on impediments to effective fishery research we have automatically emphasized some of the needs in the field. As we have explained, many of the troubles in fishery research transcend the field of fisheries and have their bases in our national character. Time and maturity will correct many present weaknesses but much can be done now to strengthen research efforts in the field of fisheries. It is difficult to make recommendations on fishery research without feeling that perhaps we cannot see the broad aspects because of the details. However, at the risk of being presumptive, we offer the following suggestions in the light of the preceding discussion:

1. Provide the proper "climate" for research; remove pressures wherever possible; pay adequate salaries; balance short- and long-term researches; insist on project completion; allow individual development and expression; do not frown upon, or consider a waste of time, literature surveys, reflection, and constructive dreaming (even the weirdest of ideas may produce surprisingly valuable results).

Of course research personnel need supervision and attention. Problems should be well defined and the programs to obtain their solutions well designed. Once the problem is assigned, provide the means to do the work—funds, labor, and facilities. Nothing is more discouraging to researchers than to receive an assignment of a problem with no provisions for conducting the investigation. Avoid frequent changes of programs and personnel, exorbitant assignment of work, unnecessary assignment of work outside the field of research, and "red tape", which all tend to lower the quality and quantity of the research.

2. Provide for free exchange of ideas and philosophies by eliminating restrictions placed on the recruitment of personnel—especially those requirements which make for provincialism and "home town" scientists. Encourage exchange of personnel between different geographical areas, travel to meetings, contacts, and conferences.

3. Provide adequate funds for research activities. Research budgets should not fluctuate widely and erratically. A dependable commitment through the years, one which will allow real planning and not require frantic, annual justification or result in alternate prosperity and poverty will yield more per dollar than any other method of financing. We must strive for high quality of work rather than for a large, showy program of poor or mediocre quality.

4. Provide for prompt and efficient media of publication.

5. Establish research centers, or institutes, supported by the states and the federal government, dedicated to the discovery of basic facts and principles, and free from the "service work" so characteristic of research units immediately subservient to administrative units.

6. Encourage fishery research in colleges and universities. Small or poorly financed fishery administrations can accomplish much for a very little by following this policy. Some of the best fishery research has been done by graduate students. Two purposes can be served for the price of one; problems are solved and men are trained.

Many universities are in an excellent position to carry on long-term investigations. The persons in charge of university research usually have long tenure, are research-minded, and in the use of student aid can so organize the project that the turnover of students does not detract from the progress. It is believed that too often universities are not aware of the major fishery problems that lend themselves to long-term research. States may cooperate to their own benefit with the universities in providing facilities, advising of problems, or in otherwise paving the way necessary for a sound long-term program.

7. Strive always to enlist the aid of specialists in other fields of science. A fishery biologist cannot be competent in every field. His research will be sounder and will yield more information if it is augmented by the contributions of chemists, biochemists, engineers, bacteriologists, physiologists, physicists, economists, and others. Because of the specialization of training given in an increasing number of universities as well as the need for specialists in research, it is believed that a somewhat new approach should be taken in recruiting fishery research staffs. Other fields, such as animal husbandry, have for some time employed, with phenomenal success, personnel equipped with specialized training in the basic sciences and with or without extensive training in the immediate field in question. Furthermore, personnel trained in other fields almost invariably bring in new ideas.

8. Promote educational programs which describe, interpret, and justify fishery research.

9. Develop better understanding between administrators and scientists through mutual effort to become acquainted with all sides of a problem.

10. Avoid impatience, intolerance for other views, and the urge to force action programs exclusively.

11. Encourage our training centers to stress quality of students rather than numbers.

COMMITTEE ON COMMERCIAL FISHERIES

W. H. R. Werner

In preparing this report, efforts were made to secure information from all areas of North America including the United States, Alaska, Canada, Mexico, and Hawaii. The latter is obviously not part of the North American continent but is economically and politically tied to the United States. However, your committee was unsuccessful in securing any information with reference to Mexico and very little about Hawaii.

I hesitate to make special reference to particular members of the Committee since all were helpful to me, but I feel duty bound to acknowledge and voice my appreciation of the very special efforts put forward by Dr. John L. Hart, whose zealous and unremitting work on a very difficult assignment was outstanding. Dr. Richard T. Whiteleather provided me with an overall picture of the United States fishery so complete that is is included almost *in toto* in this report. A similar report from Mr. George R. Clark, Assistant Deputy Minister of the Canadian Department of Fisheries, was also extremely helpful. Many other members and non-members of the Society in the United States and Canada contributed significantly, and this help is acknowledged with sincere appreciation.

The commercial fisheries showed some decline in catch during 1951. The estimated catch of fish and shellfish in the United States and Alaska totalled 4.4 billion pounds—approximately 500 million pounds less than during the previous year—although the final figures for the value is expected to remain approximately the same ($365 million to the fishermen). During 1951 about 279,000 persons were employed in fisheries work directly as fishermen, transporters and shore workers, and another 300,000 were employed in allied industries, making a total of 579,000. About 94,000 fishing craft of various types and 4,200 shore establishments were in use.

The large decline in landings was due to decreased catches of California sardine, herring in Maine and Alaska, tuna, and Pacific and jack mackerel. Fishermen failed to find the schools of pilchard, herring, and mackerel as plentiful as during 1950. Landings of tuna were very light during the last part of 1951 as the fishing fleet was tied up most of that time because of lack of markets for their products. Heavy imports severely aggravated this situation. Considerable concern is felt by the marine biologists of the California Department of Fish and Game over the sudden disappearance

of Pacific mackerel in late 1951 and in 1952. They feel that the future of this fishery is not very bright. The 1951 total landings in this state were very low, largely due to the failure of the sardine and mackerel fisheries and to the unfavorable market conditions for tuna.

The only fishery registering a large increase was salmon. Catches of this fish increased nearly 200 million pounds primarily because of a good run of pink salmon in Southeastern Alaska and on Puget Sound. The other species of salmon were generally somewhat less plentiful than in 1950. Shrimp production set a new record of over 200 million pounds during 1951 according to the estimate. The previous high for this crustacean was 192 million pounds in 1945. Menhaden landings were slightly larger than the record year, 1948, when they totalled 1,081,000,000 pounds. The fisheries of Oregon were outstanding in 1951 with respect to rosefish, dover sole and troll catches of chinook salmon. On the other hand the albacore and pilchard fisheries were a failure. Preliminary reports indicate an increase of 52 percent over 1950 in Florida's shrimp landings—35 million pounds in 1951 as compared with 23 million pounds in 1950. Production from the Campeche Banks located outside Mexico's territorial waters was the most important factor in this increase.

A number of interesting developments have taken place during the course of the year in expansion of the resource and in improved methods of taking fish commercially. Segments of the New England canning industry have shown interest in the development of the bluefin tuna resources in North Atlantic waters as a result of the exploratory fishing results obtained during the year. Experimental operations carried on by the Fish and Wildlife Service demonstrated that large quantities of 25- to 50-pound bluefin tuna, an ideal size for canning, could be taken by purse seine in those waters.

Investigations of waters in the Central Pacific area have indicated promise for the development of a longline tuna fishery where tuna have been found in considerable abundance in a band along the equator.

In the Gulf of Mexico fishing grounds for brown grooved shrimp have been expanded through exploration, and the location of red shrimp (*Hymenpenaeus robustus*) on deep water grounds in the Gulf has proved of interest. This species of red shrimp is found in depths of 200 fathoms and over. Deepwater exploration in the North Pacific Ocean off the coast of Oregon and Washington has led commercial fishermen to new banks for Pacific Ocean perch. Interest in this fishery has been stimulated by the recent decision of the Federal Food and Drug Administration to permit labelling of the species (*Sebastodes alutus*) as Pacific Ocean perch when handled in trade.

Electric reels for deepwater red snapper fishing have made their appearance in the Gulf of Mexico fisheries. Snapper vessels, pin-pointing the location of the banks through the use of Loran and then fishing with the aid of electric reels, have been able to improve their efficiency of operation considerably.

Changes are taking place in the Alaska salmon fisheries through the use of large freezer ships accompanied by fleets of fishing vessels. These ships, operating particularly in the Bristol Bay area, deliver frozen salmon to stateside ports for subsequent canning there instead of in Alaska. A couple of freezer ships have operated in Bristol Bay since the conclusion of the war, putting their catch into the trade channels as frozen fish. In 1950, however, there were 4 floaters in Bristol Bay who subsequently canned the frozen salmon in the States. This number increased to 11 in 1951, and during the current season 17 such reefers are freezing fish in Bristol Bay, currently taking about 20 percent of the total catch from that area. The principal problem experienced by the reefers was a somewhat inferior product from the standpoint of appearance and texture after canning. Research by both the industry and the Fish and Wildlife Service has resulted in considerable improvement with a resultant increased interest in this type of operation. Freezing of fish at sea to maintain highest quality of the product has caught the interest of industry in New England through experimental programs being conducted by the Fish and Wildlife Service. These experiments in freezing fish at sea for later defrosting on shore where fillets are cut from them, packaged and refrozen, has shown much promise as a means of retaining the best qualities of the fish until it reaches the consumer.

From the standpoint of fisheries management in Alaska, the biggest change in 1951 was the initiation of a fish ticket system for recording catches of all forms of fish and shellfish in the Territory. While valuable in the gathering of straight statistics, this system was largely designed to provide specific data as to gear, geographical location of catch, time of catch, etc. These data are tabulated on IBM punch cards and subsequently machine analyses are made for the use of district management biologists in analyzing trends in the various runs.

Probably the most outstanding trend in the preparation of fishery products has been the rapid increase in breaded fishery products. Breaded shrimp, packaged and frozen, has met with extensive consumer favor throughout the United States. During 1951 the production figures shot upward when there were several million pounds produced in the United States. Many fishery firms have also offered breaded fillets as a time-saving device for the consumer in preparation. These factors demonstrate the over-all trend toward consumer packaging which started in the fisheries a number of years ago and which continues to go forward rapidly.

Technological studies successfully carried out on the utilization of salmon cannery waste in Alaska achieved specific results during 1951. Bids were placed for a sizable quantity, one-half million pounds, of salmon eggs and other waste from salmon canneries, for use of this material as fish feed in hatcheries. Adequate means of packaging this material for transportation at a low cost has been responsible in a major part for this achievement. Finding a use for salmon cannery waste, of which there are

quantities totalling millions of pounds each year, is a solid step toward better utilization of the resource, or in other words, conservation.

The Fish and Wildlife Service has been studying the haddock population on Georges Bank for many years and has now accumulated sufficient information on the habits and life history of this fish to feel that predictions of catch can be made. They have predicted a catch of 89 million pounds of haddock from this bank in 1952.

In the Great Lakes, investigations with reference to the sea lamprey have been carried on intensively for 4 or 5 years now with a view to controlling this parasite. In 1951 the Fish and Wildlife Service investigated the possibilities of blocking the lamprey spawning runs by means of electrical devices. Various types of these devices were installed in six separate drainages. They have had considerable success in stopping the spawning run by this method at very low cost both in capital outlay and maintenance when compared with the cost of mechanical weirs. It was also found that by proper design a fair percentage of the fishes associated with the sea lamprey run could be salvaged. Various investigations incidental to the sea lamprey control program were being brought to conclusion during the past year. A study of the feeding habits and food requirements of sea lampreys is now being written up and a rather exhaustive study of the physiology of feeding and its effect on host fishes is also in the process of writing. Preliminary experiments intended to discover, if possible, a selective poison for sea lamprey larvae are practically complete. The preliminary tests yielded several promising compounds which showed a rather distinct differentiation in killing effect when applied to sea lamprey larvae and goldfish in the same tank. Further experimentation is intended to explore the possibility of using these chemicals as larvicides in the field. A study on the life history of the dwarf population of sea lampreys inhabiting the Finger Lakes of New York is in its final stages. A report on this work will be completed by the end of this summer.

During 1951 the landings of commercial fish in Canadian waters amounted to about 1.3 billion pounds, a decrease of about 35 million pounds from 1950. The landed value of these fish was about $95 million and the estimated marketed value just under $200 million, an increase of about $20 million over the preceding year. The 1950 catch was taken by 65,037 fishermen and 14,861 persons were employed in the first processing of this catch. They used 2,232 vessels and 36,280 smaller boats. The investment in fishing craft was $51,035,900 and in fishing gear $29,082,200.

The British Columbia fisheries progressed in value from $68 million in 1950 to $86 million, exceeding all previous figures. The pack of canned salmon was higher than any figure for the past ten years. Salmon prices significantly advanced over those in 1950, the canned pack being valued at $47 million.

The market value of the Atlantic fisheries, including Newfoundland, was estimated at about $95 million. The catch was slightly less than in 1950,

but prices were generally better, due to improved marketing conditions of fresh, frozen and salted products.

The freshwater fisheries yielded a better catch than in 1950 with prices generally higher. Total landings were about 95 million pounds against 92 million in the preceding year. The value marketed was in the vicinity of $21 million against $18.5 million in 1950.

There was a net gain of $5.4 million in the gross income to fishermen of the Pacific Coast from 1950 to 1951. This gain was almost fully attributable to the results obtained in salmon fishing. Compared with the previous year, average prices to fishermen for all species of salmon were 13 percent better, sockeye and pink prices increasing by as much as 30 percent. Other species of fish such as sole, greycod, lingcod, sablefish, etc., were also higher priced in 1951 than in 1950. However, the halibut price averaged 17 percent less in the past year than in 1950. The pack of canned salmon, at 1,956,396 cases was a ten-year record. However, sales of fresh and frozen salmon to the United States were down from 42 million pounds and $10.6 million in 1950 to 26.6 million pounds and $7.5 million in 1951.

The yield of the Atlantic Coast fisheries was less in 1951 than in 1950 but increases in prices paid to fishermen for many species of fish have kept the gross income position of the fishermen at an equivalent level in the past two years. The value of the fisheries at the fishermen's level was $33 million in 1951 for the Maritimes and Quebec, compared with $32.7 million in the preceding year. No corresponding figures are available for the Province of Newfoundland but it is estimated that, despite some decline in catch in this province also, better marketing conditions in 1951 somewhat offset a possible decline in income by a lower yield.

The catch in the Maritimes and Quebec was 705 million pounds, 31 million pounds less than in 1950. This was mainly attributable to a low yield of the cod, herring, halibut and clam fisheries. However, the prices paid the fishermen were generally 4.3 per cent better than in 1950. Compared with the preceding year, the price of cod was up by 10 percent and that of sardines by 100 percent. On the other hand, lobster prices averaged 6 percent less.

The year 1951 was one of consolidation for Canada in the field of fish marketing. There had been a considerable re-arrangement of the marketing pattern during the preceding few years as the industry adapted itself to a fundamental change in the nature of its markets. On the one hand, a number of established markets for traditional products had become difficult or impossible of access because of impediments and restrictions arising out of the exchange difficulties of the non-dollar countries. On the other hand, the rapid development of food merchandising in North America, particularly in the packaging, transportation and display of frozen foods, offered the fishing industry new chances in the Canadian and U. S. markets, of which it took advantage. Continuing general economic prosperity and limited supplies of other foods facilitated the industry's task. As a result, the production of such former staple commodities as salted dried

codfish was allowed to decline, while the output of fresh and frozen products, particularly fillets, was increased. At the same time, successful attempts were made to persuade the domestic consumer to buy greater quantities of other fishery products, such as canned fish, which before had been sold mostly abroad. As a result, fish consumption in Canada in 1951 reached a new high of 13.7 lbs. edible weight per capita of population and about 70 percent of Canadian fishery exports continued to flow into the U.S.A. It might be noted that the expansion of the North American market was based upon a high level of purchasing power, upon increased sales facilities, and not upon any reduction in prices.

In 1951 a sales slip system was put into operation for collecting fisheries catch statistics on the West Coast of Canada. The sales slip system is not new, as it is in operation, for instance, in the States of Washington and California. In addition to the amount of fish purchased, British Columbia sales slips indicate the area of the catch, the gear used and the number of days fishing. They thus supply the basic information which satisfies the needs of the biologists as well as those of the economists. As indicated earlier in this report this system appears to be similar to that used now in Alaska.

The old system of collecting catch statistics on the West Coast of Canada was not fully satisfactory for the biologists as the information was compiled by districts in which the fish was landed. In contrast the new system gives much more adequate data on areas fished in British Columbia where of late there had been a tendency to reduce the number of canneries with a resultant concentration of processing plants.

For the first time in Canadian history, a fisheries census was launched in Canada in 1951, along with the general decennial census. A record of all fishermen was taken according to categories of income. Each person having caught a hundred dollars worth of fish or more and/or having spent 15 days or more in fishing was recorded as a fisherman.

The Canadian Department of Fisheries includes an Inspection and Consumer Service among its components. Previous to this Service being inaugurated in 1950, the duties of protection and inspection were carried out largely by the same personnel. The newly created Inspection Branch of this Service permits more emphasis and specialization to be placed on the inspection of fish and fish products. Results have indicated that the efficiency of inspectors has increased since this change in establishment became effective.

In 1951 compulsory inspection of whitefish for export was established and is administered by the Inspection Branch. Buyers of Canadian whitefish have found that application of the regulations has resulted in a uniformly higher quality reaching the export markets in the United States. These new regulations, to ensure that only the highest quality whitefish products are exported, resulted from a close study of the problem by the provincial governments concerned, the fishing industry itself, and the Canadian Department of Fisheries.

The Consumer Branch of this Service was created for the purpose of helping to increase the domestic consumption of fish and fish products in Canada. The prime duties of this Branch are to interest housewives, hotels, restaurants, railways, institutions and all potential protein food consumers in the purchasing, preparing and eating of fish and fish products.

In looking over material for this report an interesting news item from the *Montreal Gazette* of July 15, 1952, republished in the *Bulletin of the Fisheries Council of Canada* attracted my attention. It reads as follows:

"A new electric refrigerator on wheels, the first of its kind on the continent, came off the assembly line at the Canadian National Railways car shops yesterday and underwent a standing test of its icing equipment. On its running tests, scheduled to begin this week, officials expect the temperature of the car will dip to 10 degrees below zero. This is 15 degrees lower than the average temperature obtained in ice 'reefers'. A. C. Melenson, C.N.R. chief of motive power and car equipment, said that it is the first time that a mechanical reefer car has been built with its refrigeration equipment suspended beneath it. The innovation is made possible by using suspension gear and an air circulating system both designed by engineers of the C.N.R.'s car department.

In addition to its refrigerating qualities, the new car can also provide heat in the wintertime. A flick of a switch transfers power from the cooling apparatus to a bank of electric heaters in the ceiling. The car's first running test will begin Friday when it leaves Toronto for Halifax carrying a load of fresh beef. On its return run to Montreal it will carry a shipment of frozen fish. Later this summer it will run eastward from British Columbia with a load of peaches. The tests will be made under the supervision of J. L. Townshend, general supervisor of perishable traffic for the C.N.R. (In late August this car will leave Prince Rupert with a load of fish, being compared on this run with other cars carrying fish under a variety of icing conditions.)"

COMMITTEE ON NAMES OF FISHES

Reeve M. Bailey [1]

Since publication of "A List of Common and Scientific Names of the Better Known Fishes of the United States and Canada" (Am. Fish. Soc., Spec. Publ. 1, 1948), this Committee has concerned itself chiefly with a thorough reconsideration of some of the more debatable names on the list. Last year (Trans. Am. Fish. Soc., Vol. 81, p. 325) we recommended continued use of 8 names that had been challenged and approved changes for 10 others. In addition, certain minor emendations in the list were made. A year ago the names of 13 species were under discussion and for them decision was deferred pending more thorough consideration. We

[1] In the absence of the chairman, the report was presented by Frank T. Knapp, member of the Committee.

now report adoption of amended names for 7 of these, recommend retention of the *status quo* on 1, and continue our study of 5 others.

Stability in nomenclature is a prime objective of the Committee, hence we have regarded seriously the problem of change. A simple majority vote is considered adequate for the original acceptance of an entry in the list, but it is our operational procedure to demand that two-thirds of the Committee approve suggested changes prior to their adoption. The names for which we now recommend change are as follows:

Number in list	*Newly approved common name*	*Scientific name*	*Vote of Committee (for the change)*
104	Coho Salmon	*Oncorhynchus kisutch*	6–1
105	Sockeye Salmon	*Oncorhynchus nerka nerka*	7–0
107	Chinook Salmon	*Oncorhynchus tshawytscha*	7–0
374	Smallmouth Bass	*Micropterus dolomieui*	6–1
375	Spotted Bass	*Micropterus punctulatus*	6–1
376	Largemouth Bass	*Micropterus salmoides*	6–1
377	Redeye Bass	*Micropterus coosae*	6–1

A proposal to add the name lake herring as coequal with shallowwater cisco (No. 120) is denied (vote: 4–2 against). The presently accepted names of the 5 species still under study (No. 35—mackerel shark; No. 91—skipjack; No. 339—dorado; No. 442—bluestriped grunt; No. 474—rosefish) are objected to by several or all of the committee members. However, it is not yet determined what substitute names, if any, are more appropriate. Since no new petitions for name changes have been received, it appears that this phase of the Committee's work—that of amending unsatisfactory selections on the original list—is essentially complete.

Your Committee has been requested to explore the question of capitalization of vernacular names of fishes, a practice, for example, that is widely though not universally employed in ornithology. Opinions were elicited from many workers. After thorough consideration, the committee members, when polled on the proposition "Do you favor the capitalization of common names in the *Transactions* and in *Copeia?*", replied unanimously in the negative.

Acting on a suggestion by the then president of the American Society of Ichthyologists and Herpetologists, Dr. George S. Myers, this Society at its Rochester meeting approved the appointment of a Committee on Common Names of Fishes in the A.S.I.H., to consist of the same members as the equivalent committee in the A.F.S. This Committee has since been created by the A.S.I.H., and the two organizations are working as a team to realize the objectives for which the A.F.S. Committee was established.

In an independent effort to stabilize common names of American sport fishes, the Outdoor Writers Association of America has a committee on names and has issued a number of printings of their list. Our respective committees have been maintaining cordial relations and have interchanged views on controversial matters. Changes in the two lists are gradually reducing the conflicts in usage. Despite the recency of publication of the

lists, it is obvious that marked progress has been achieved in the stabilization of common names.

For some species, numerous complexities surround the establishment of a generally acceptable common name. This is especially true of fishes which are widespread geographically and have been tagged with diverse vernacular names in different parts of their ranges. For fishes of importance both to sport fishermen and to the fishing industry it is likewise difficult to obtain uniformity. In wrestling with some of these problems the Committee has realized the difficulty of operating without a set of principles to govern selection of vernacular names. Some few guiding precepts were set forth in the List of Names, but in large part the choices were established subjectively, as expressions of the experience, whims, and tastes of the committee members. The Committee has not been operating in a void, for each member has his own set of guides, whether or not these are clearly formulated. But there exists a clear-cut need for general agreement on a steering mechanism. For this reason your Committee is now engaged in an effort to establish a series of principles with which to measure the appropriateness of any given name or to select from a series of alternative possibilities. We hope soon to be able to present the results of this endeavor to the Society.

This establishment of guiding principles is regarded as an essential precursor to the gradual expansion of the list, which the Committee agrees unanimously is a needed future development. In its present scope the list excludes almost all species that are not of importance as sport or food fishes. Changes in and expansion of the present list will of course lead to republication when that becomes necessary.

MEMBERSHIP COMMITTEE

Ralph Hile

The report of the Membership Committee can hardly be other than anticlimatic and perhaps could profitably be dispensed with, since, before it is given, the Secretary's report already has established the current status of membership. We are deeply gratified to learn that recruitment has been good during the year and trust that our efforts have contributed to the increase. We realize, nevertheless, that the accomplishment possible to a small group of ten is limited. Each of us has no doubt recruited several members personally—in fact, some members of the Committee exhibited truly outstanding enterprise. On the other hand, major credit must go to the members of the Society at large who heard our pleas for assistance and to the perennially faithful hunters who never pass an opportunity to track down a likely prospect. Our Society has grown and will continue to grow through the efforts of all.

REPORT OF SPECIAL COMMITTEE

COMMITTEE ON EMPLOYMENT AND PROFESSIONAL STANDARDS

T. H. Langlois

The Committee on Employment and Professional Standards has had considerable difficulty in holding a meeting, and correspondence is not too satisfactory as a means of achieving agreement on the concepts and recommendations. Three of us at Dallas have attempted to formulate a few points on which there has been substantial agreement. These three are Dr. Schneberger, Dr. Carlander, and myself. We feel that there needs to be some appraisal of curricula at the various institutions which are involved in training fishery personnel. Such an appraisal should be merely a listing of curricula without passage of judgment at this time. Such surveys should be prepared in reprint form to send to prospective students and vocational guidance personnel. Those are the people who are inquiring about and wishing that kind of information.

We think that the time is right for the development of fisheries engineering as a profession. We suggest that consideration be given to the development of fishery consultant service as private enterprises. Many problems on private lands are not properly the responsibility of governmental agencies although at the present time the only experienced personnel may be found in Government service. It is felt that this committee should not attempt to set up an employment agency.

ELECTION OF HONORARY MEMBERS

Upon submittal of petitions bearing the names of 10 members in good standing, the following were elected by unanimous vote to honorary life membership in the Society:

August J. Anderson, Marquette, Michigan

Charles O. Hayford, Hackettstown, New Jersey

Emmeline Moore, Slingerlands, New York

J. A. Rodd, Ottawa, Ontario

John Van Oosten, Ann Arbor, Michigan

REPORTS OF SESSIONAL COMMITTEES

COMMITTEE ON TIME AND PLACE

RICHARD CROKER

The Committee on Time and Place met with the corresponding committee of the International Association of Game, Fish, and Conservation Commissioners. Acceptance was recommended of the invitation issued by the State of Wisconsin. Later, at a meeting of the executive committees of the two societies, it was agreed that the 1953 meeting of the American Fisheries Society shall be held in Milwaukee, Wisconsin, September 16–18 and the meeting of the International Association of Game, Fish, and Conservation Commissioners September 14–16.

AUDITING COMMITTEE

LEONARD JOERIS

The Auditing Committee has examined the accounts of the American Fisheries Society for the fiscal year 1951–1952 and found them to be correct. The Committee wishes to commend the Secretary-Treasurer and his assistants for the exemplary handling of the accounts of the Society.

RESOLUTIONS COMMITTEE

H. S. SWINGLE

1. Special Committee on Publication of Transactions

WHEREAS, The membership of this Society has been constantly expanding, the articles submitted for publication have been increasing, and

WHEREAS, The work involved in editing the Transactions has been increasing accordingly and has reached a point where it is difficult to find qualified members who can accept this responsibility in addition to their regular work; now therefore

BE IT RESOLVED, That the President appoint a special committee of three members to study this problem and report their recommendations to the Executive Committee for action. The committee shall be instructed to investigate the possibilities of contracting for editorial assistance with publication divisions of universities, with the American Institute of Bio-

logical Sciences or other organizations, the possibility of establishing a joint editorial staff serving several societies, and other methods of relieving the burden upon the Editorial Board.

2. Proposed Amendments to the By-Laws

WHEREAS, The maintenance of a high standard of content and prompt publications of Transactions is of paramount significance to the function and progress of the American Fisheries Society, and

WHEREAS, suitable editorial procedure and proper scheduling of publication is becoming increasingly difficult of attainment under the present provisions of our By-Laws; now therefore

BE IT RESOLVED, That to alleviate in part these difficulties our By-Laws should be and are hereby amended as follows:

Section 6 shall be revised to read: The minutes and proceedings of regular and special meetings of the Society and of any regional division established pursuant to Article VI of the constitution, together with reports of officers and committees at such meetings, technical papers furnished by members and selected by the Editorial Board for publication and the official membership list of the Society shall be published in an annual volume which shall be numbered in series with the preceding volumes and shall be entitled "Transactions of the American Fisheries Society." Each active member, life member, library member, sustaining member, and official member shall receive one copy of the annual volume of Transactions. Honorary members shall be sent a copy of each volume of Transactions only on receipt of written request therefor. Special publications may be written with the direction or with the approval of the Society or the Executive Committee at any official session.

The first sentence of Section 7 shall be revised to read:

Only members in good standing may present papers either by reading or by title at the annual meetings of the Society, or submit them for publication by the Society; except that outstanding non-members, invited by the President of the Society or the Secretary-Treasurer with the advice of the President, who presents papers at any meeting shall be exempt from this requirement.

The title of Section 12 shall be changed from Editorial Committee to Editorial Board, and the section shall be revised to read: The Editorial Board is that committee responsible for the editing and publication of the Transactions and of any special publications of the Society. Its Board shall consist of five members in good standing of proved technical and editorial abilities each of whom shall serve for a term of five years. Each President immediately upon his election shall appoint one new member of the Board and shall designate the Chairman for the ensuing year. The Chairman of the Editorial Board shall be known as the Editor, and other members shall be known as Associate Editors. The Editor shall assign duties to the Associate Editors and may solicit assistance from time to time for temporary periods from other members of the Society. The Board is

authorized to establish and issue such standards and instructions to the membership as may facilitate its work. The Board shall report to the Society annually concerning its work.

BE IT FURTHER RESOLVED, That to effectuate the changes recorded above the present Editorial Board is hereby abolished and the President directed to appoint a new Editorial Board in accordance with the provisions of the amended By-Laws which committee shall be composed of members serving staggered terms of from one to five years.

3. Review of Fisheries Publication

WHEREAS, The members of this Society believe that the exchange of information on fisheries and management activities is desirable, and

WHEREAS, There is now no clearing house for such information; now therefore

BE IT RESOLVED, That the Secretary of this Society is hereby directed to request the Director of the U. S. Fish and Wildlife Service to initiate the necessary action wherein the Dingell-Johnson Division of the Federal Aid shall collect such information on fishing research activities irrespective of financial support of such projects and make that information available to the several states and other interested agencies.

4. Water Pollution

WHEREAS, The problem of water pollution continues to be a serious problem confronting the American public, and

WHEREAS, There is a pressing need for support for measures and programs that will ameliorate and control water pollution; now therefore

BE IT RESOLVED, That the President appoint a committee to consider the problem of water pollution including progress toward its prevention and control and to recommend action by the American Fisheries Society and its membership in support of pollution abatement programs and that this committee shall report at the next meeting its findings and recommendations to the Society.

5. State Control of Hunting and Fishing on Federal Lands

WHEREAS, Many of the states of the Nation have extensive Federal lands within their borders, and

WHEREAS, Fish and game are present within these areas which are administered by various Government agencies and military posts and are limited to access by military personnel approved by these agencies, and

WHEREAS, All laws recognize that the fish and game of the Nation are the property of all the people of the Nation and held in trust for them by the state agencies so designated; now therefore

BE IT RESOLVED, That the American Fisheries Society does hereby recommend legislation by Congress to provide that any hunting or fishing

on Federally-owned or managed land must be done in accordance with the game and fish laws in the states where these lands are located, and

BE IT FURTHER RESOLVED, That the Secretary of the American Fisheries Society so advise the Directors of the Game and Fish Commissions of the various states so that they may take action.

6. Expression of Gratitude

WHEREAS, The Wisconsin Conservation Commission and Department have assisted the Society in many ways and have been generous with clerical aid and have been especially helpful to our Secretary-Treasurer; now therefore

BE IT RESOLVED, That the Society extend its thanks to the Wisconsin Conservation Commission and Department for this greatly appreciated favor.

7. Appreciation of Hospitality

Whereas, The Dallas, Texas meeting of the Society has been an outstanding success, and

WHEREAS, The members and guests have enjoyed exceptional hospitality; now therefore

BE IT RESOLVED that the American Fisheries Society express its sincere appreciation and profound gratitude to the State of Texas, the City of Dallas, the Baker Hotel, and to Mr. Marion Toole and other members of the staff of the Texas Game and Fish Commission who have combined to make this meeting a success.

NOMINATING COMMITTEE

ALBERT S. HAZZARD

Mr. President and members of the Society, the Nominating Committee has the honor to submit the following slate:

OFFICERS

President .....Ralph Hile, Michigan
First Vice-President .....Fred A. Thompson, New Mexico
Second Vice-President .....Andrew L. Pritchard, Ontario
Secretary-Treasurer .....George E. Sprecher, Wisconsin
Librarian .....William C. Beckman, Colorado

Committee on International Relations

William C. Herrington, Virginia, *Chairman*
James Brown, Louisiana
Wilbert A. Clemens, British Columbia
Richard Croker, California
A. G. Huntsman, Ontario
Fernando Obregon, Mexico
Stillman Wright, District of Columbia

Committee on National—State Relations

John Gottschalk, Virginia, *Chairman*
R. W. Eschmeyer, District of Columbia
Clarence F. Pautzke, Washington
Francis W. Sargeant, Massachusetts
Ernest Swift, Wisconsin

Committee on Hydrobiology and Fish Culture

A. V. Tunison, District of Columbia, *Chairman*
James H. Cornell, North Carolina
Clarence E. Cozort, Oklahoma
F. E. J. Fry, Ontario
Charles N. Lloyd, Wisconsin
Richard B. Miller, Alberta
James C. Simpson, Idaho

Committee on Commercial Fisheries

John L. Hart, British Columbia, *Chairman*
John F. Dequine, Florida
Gordon Gunter, Texas
George Y. Harry, Jr., Oregon
W. H. R. Werner, Ontario
Richard T. Whiteleather, District of Columbia
A. H. Underhill, New Jersey

Committee on Names of Fishes

Reeve M. Bailey, Michigan, *Chairman*
Frank T. Knapp, Texas
Ernest A. Lachner, District of Columbia
John C. Marr, California
George S. Myers, California
Edward C. Raney, New York
William E. Ricker, British Columbia

DR. HAZZARD: Mr. President, I wish to place these names in nomination and recommend their election.

PRESIDENT HARKNESS: What is your pleasure?

DR. LANGLOIS: Mr. President, I think the Nominating Committee has prepared a fine slate, but I think we completely overlooked one major item in the procedure that has been followed for a great many years by the Society, namely, the succession that leads to the Presidency. We have had a rule, not a written rule, if you please, but a rule that has been pretty well followed, nevertheless, that the President's office should be held in this order: A Canadian, a State man, and then a Federal employee. I think there is merit to that type of rotation. I think it would be in order to elect a Federal representative for the position of Second Vice-President. One of our long-standing and very active members has been Dr. O. Lloyd Meehean. He has never held a top office in this organization although I think his service merits it. I take great pleasure in nominating Dr. O. Lloyd Meehean to the position of Second Vice-President.

MR. DEQUINE: I would like the privilege of seconding that nomination.

PRESIDENT HARKNESS: We have had a nomination which has been seconded. Are there any further nominations for this particular office, of Second Vice-President? Are there any nominations for other officers?

DR. HAZZARD: Mr. President, I would like to remind Dr. Langlois that we are following the succession that he has mentioned. Dr. Hile, the nominee for President, of course, represents the Federal service, Mr. Fred Thompson, the State service, and Andrew L. Pritchard represents the Federal service of Canada. I wonder if the Nominating Committee has neglected tradition in presenting the slate that we have.

DR. LANGLOIS: My apologies to you. I misunderstood that sequence. I thought you overlooked an important point. I wish to call your attention to the fact that Dr. Meehean ought to be in line for this position in the near future, and with that understanding I would like to withdraw that nomination.

PRESIDENT HARKNESS: Dr. Langlois has withdrawn his motion.

MR. DEQUINE: Mr. President, with all deference to Dr. Langlois' remarks and with no aspersions cast upon Dr. Pritchard, I can recall two years ago at Memphis when the Society departed from that tradition in the nomination of officers, and in view of that fact and in view of my own personal desires in this matter I wish to make a new motion that Dr. Meehean be nominated for Second Vice-President of the Society.

PRESIDENT HARKNESS: Are there any further nominations? I will entertain a motion that the nominations be closed.

MR. TOOLE: I move that the nominations be closed, and that the Secretary be empowered to cast an unanimous ballot for the slate, except Second Vice-President.

[The motion was seconded and passed.]

PRESIDENT HARKNESS: We shall now ballot for the position of Second Vice-President. We have nominations for Dr. Andrew L. Pritchard and for Dr. O. Lloyd Meehean. A two-thirds vote is necessary. You are reminded that only members in good standing may vote. Any member who suspects that some person is not a member in good standing not only has the privilege but has the responsibility of challenging his vote. I would like to appoint as ballot clerks two past presidents—Mr. Charles Hayford and Dr. H. H. McKay.

You will recall I announced a two-thirds vote was necessary. The first ballot was as follows: Dr. Andrew L. Pritchard—50; O. Lloyd Meehean—36. It is not a two-thirds majority, so we will have new nominations and a second ballot.

DR. HAZZARD: On behalf of the Nominating Committee I would like to present again the name of Andrew L. Pritchard for Second Vice-President.

MR. DEQUINE: I nominate Dr. Meehean for Second Vice-President.

MR. WERNER: I move the nominations be closed.

[The motion was seconded and passed.]

PRESIDENT HARKNESS: The returns of the second ballot are: Dr. A. L. Pritchard—

60, Dr. O. L. Meehean—46. We still do not have a two-thirds majority for either of the nominated candidates. I wish to call again for nominations from the floor.

DR. HAZZARD: On behalf of the Nominating Committee we would again like to present the name of Dr. Andrew L. Pritchard for the office of Second Vice-President.

MR. GOTTSCHALK: I move that the nominations be closed.

[The motion was seconded and passed.]

MR. GORDON: I now move that the Second Vice-President be elected by acclamation.

[The motion was seconded and passed.]

MR. DEQUINE: In view of the recent difficulties in the election of the Second Vice-President I should like to move that from this time forth the Nominating Committee be required to submit at least two names for that position.

[The motion was seconded.]

MR. GORDON: Mr. President, I do not think that anyone in this room is unsympathetic to the desire of the gentlemen who are proposing this amendment to our By-laws, but I believe that in an organization of 1,400 members we ought to present and vote on it in an orderly way, and it does seem to me that, if an amendment is to be made to either the By-laws or the Constitution, the specific wording of that amendment should be submitted as a part of the motion so that everyone will know exactly what they are voting upon. It would not be fair to impose upon the Secretary even though he is one of the most capable Secretaries we have ever had, the responsibility for drafting an addition to the By-laws. It seems to me that would not be good procedure.

PRESIDENT HARKNESS: I agree with you Mr. Gordon, but we have a motion which has been seconded. Is there any further discussion? Are you ready for the question?

[The question was called for and the motion failed.]

CONCLUDING BUSINESS

DR. MEEHEAN: I move that Dr. Lloyd L. Smith, Jr. be thanked by the American Fisheries Society for long and fine service on the Editorial Board.

[The motion was seconded and passed.]

PRESIDENT HARKNESS: I shall bring the meeting to a conclusion very quickly. I have heard several comments that this meeting has been a very successful one and any success is directly attributable to the local committee and the very fine work that Mr. Marion Toole and his group have done.

Are Mr. Seaman and Mr. Croker here? Would you gentlemen please conduct Dr. Ralph Hile, our President, to the rostrum?

PRESIDENT-ELECT HILE: I do thank you fellow members very much for having conferred upon me the honor and the privilege of serving you as your President during the coming year. It is not for me to comment on the soundness of your judgment in this action, because I certainly should be guilty of bias unbecoming one who has spent so much time in scientific pursuits.

I should like to assure you that throughout the coming year I shall exert every effort to make certain that your judgment has not been betrayed by your charity. Your Society is now at its highest membership record. What is more important, I believe, it has attained equal status in usefulness. I do not propose that during my term of office we shall let it pass into a period of decline. I shall do the best I can with this fine slate of officers and committees that has been appointed. Thank you again.

I can only second the statement of Dr. Harkness in thanking all the members that participated in the meeting and the local committee for their fine work. Is there any further business?

MR. WADE: From Augusta, Maine, to Dallas, Texas, is quite a long trek. It has been my privilege for many years to have been in attendance at a great many meetings of the American Fisheries Society. My purpose in coming to the meetings throughout the years has been that I might gain some knowledge, information, and facts that would benefit me in my work as a fish-culturist.

Here at Dallas I listened very attentively to the program in its entirety. I listened with a great deal of respect to that portion of the program that had to do with the division of the American Fisheries Society geographically. I have the privilege to be a member of the Northeastern Division. I have talked with members of the Western Division. I now understand that we are to have a Southern Division of the parent organization. It has been my experience that these divisions of the parent organization are drawing a great attendance, and with all due respect to those who took part in the program of this particular meeting, the divisional meetings seem to offer a more factual type of program than that which I have heard at this particular meeting.

I am fully appreciative, Mr. President, of the fact that my remarks here tonight are going to meet the disapproval of a great many members of the American Fisheries Society, but I do feel personally that we are on the threshold of having to determine where we are going. I listened with admiration to our Secretary-Treasurer's report of the membership. Yet as I sat here listening to a few titles and a few abstracts, and I wonder if it might not be profitable to me as an individual to sit back in the State of Maine and wait until the Transactions have been printed so that I might read the papers in their entirety.

I don't know how my remarks are going to be taken by the majority of the members here, but I as an individual have felt that something is very definitely lacking in this particular meeting with respect to the knowledge which we hoped to gain from coming here. I wonder if our regional organizations are not going to detract from the

meeting of the parent organization. It seems to me that, unless we get back to something more fundamental, than has been exhibited in this particular meeting, that we are failing to serve the purpose of our annual sessions.

PRESIDENT HILE: Certainly no organization ever was injured by a frank statement of the problems that confront it. We are all perfectly aware of the dangers that go with regionalization. We are aware of it now and were aware of it at the time the movement started. Only time will tell how great the harm may be to the functioning of the Society as a whole. If the regional meetings do become actually a substitute for the central meeting rather than a supplement to it, the damage to the Society will be great, indeed. I think that here is a problem for the members to consider after they have gone home. Certainly, we must not let the regional divisions injure the Society as a whole.

DR. HARKNESS: Mr. Gordon has brought to my attention that a paper is to be given by Mr. Gutermuth on this very question of regional organizations. Those of you who are here next Friday should hear that paper.

PRESIDENT HILE: If there is no further business to come before the Society, I can accept a motion for adjournment.

MR. CROKER: I move we adjourn.

[The motion was seconded and passed; at 10:15 P.M., the proceedings were adjourned *sine die*.]

Appendices

CONSTITUTION OF THE AMERICAN FISHERIES SOCIETY

(Revised 1952)

ARTICLE I

Name, Objectives and Purposes

1. The name of the organization shall be the American Fisheries Society, hereinafter referred to as the Society.

2. The objectives and purposes of the Society shall be:

(a) To promote the conservation, development and wise utilization of the fisheries, both recreational and commercial.

(b) To promote and advance the development and application of all branches of fishery science and practice, including aquatic biology, engineering, economics, fish culture, limnology, oceanography and technology.

(c) To gather and disseminate technical and other information on fishes, fishing, fisheries, and all phases of fishery science and practice.

(d) To hold meetings for the presentation, exchange, and discussion of information, findings and experience on all subjects and techniques related to fishes, fishing, fisheries, and all phases of fishery science and practice.

(e) By such other means as may be appropriate, to unite and encourage those interested in fishes, fishing, fisheries, and all other phases of fishery science and practice.

ARTICLE II

Membership and Election of Members

1. The membership of the Society shall be of the following classes:

(a) *Active Member:* Any person interested in the Society and in the furtherance of its purposes and objectives is eligible for election as an Active Member.

(b) *Life Member:* Any duly-elected active member, upon payment of the fee for life membership as specified in the By-laws, may retain his status as an active member throughout the remainder of his life and shall be exempt from any further payment of dues.

(c) *Sustaining Member:* Individuals, any sporting or fishing club, any society, corporation or other organization is eligible for election as a sustaining member.

(d) *Library Member:* Any technical, public, private, or other library may become a library member.

(e) *Official Member:* Any Federal, State, Provincial, or Territorial department or agency of the United States of America, Government of Canada, United Mexican States, or any other American Republic is eligible for election as an official member.

(f) *Patron:* Any person, society, club, firm, corporation, or other organization is eligible to become a patron.

(g) *Honorary Member:* The President of the United States of America, the Governor-General of the Government of Canada, the President of the United Mexican States, the Governors of the States and Territories of the United States of America, the Lieutenant-Governors of the Provinces of Canada, the Secretary

of the Interior of the United States of America, the Minister of Fisheries of Canada, and the Secretary of the Marine of Mexico shall be honorary members of the Society while serving in such official position. Any other person of note, by reason of his professional or other attainments, outstanding service to the Society, or his official position, shall be eligible for election as an honorary member.

2. Nominations for active membership, sustaining membership, library membership, official membership, and patron shall be submitted to the Secretary-Treasurer with the endorsement of at least one active member of the Society. Except as provided in paragraph 3, such nominations shall be presented to the members present at any regular or special meeting and shall be considered elected if they receive an affirmative vote of a majority of the members present at such meeting. Nominations for honorary membership shall be submitted with the endorsement of at least ten active members of the Society in good standing, and the unanimous vote of all members present at any regular or special meeting shall be required for election.

3. The Executive Committee, established pursuant to Article III, is authorized to consider and vote upon nominations for all classes of membership, except nominations for honorary membership, during the intervals between meetings. When so authorized by the Executive Committee, the President of the Society and the Secretary-Treasurer, acting jointly, may pass upon such nominations during the said intervals.

4. The names of elected members shall not be added to the membership rolls of the Society until they have paid such dues, fees or assessments for a period of at least one year as are enumerated in the By-laws adopted pursuant to Article V.

5. As used in this Constitution, and in the By-laws adopted pursuant to Article V, the term "member in good standing" means any active member, life member, sustaining member, or official member, whose dues are not more than one year in arrears; provided that a sustaining member or an official member shall be entitled to one vote.

ARTICLE III

Officers and Executive Committee

1. The officers of the Society shall be a President, a First Vice-President, a Second Vice-President, a Secretary-Treasurer, and a Librarian.

2. Only members in good standing who have been in attendance at one of the two regular meetings preceding their nomination or election shall be eligible for such nomination or election to one of the offices named in paragraph 1. Members who accept nomination and are elected to hold one of the offices of the Society, are bound to perform their duties to the best of their ability and to advance the purposes and objectives of the Society.

3. Officers shall be elected and serve for a period of one year, or until

the next regular or annual meeting, and shall (with the exception of the Secretary-Treasurer and the Librarian) be ineligible for reelection to the same office for a period of one year after the expiration of their terms of office.

4. The officers named in paragraph 1, the President of the preceding year, the chairman of any regional division established pursuant to the provisions of Article VI, and the chairman of any standing committees established in accordance with the By-laws adopted in accordance with Article V, shall constitute the Executive Committee. The Executive Committee is authorized to decide the policies of the Society, and to transact such business of the Society as may be necessary between regular or annual meetings.

5. In the event of the cancellation of a regular or annual meeting, the officers enumerated in paragraph 1 of this Article and the members of any standing or special committees established in accordance with the By-laws adopted in pursuance of Article V shall continue to serve until such time as a regular meeting can be scheduled at which new officers shall be elected and new committee members elected or appointed.

ARTICLE IV

Meetings and Voting

1. The Society shall meet once a year at a time and place to be decided upon by the membership at the preceding regular or annual meeting, or, in default of such decision by the membership, by the Executive Committee. Special meetings may be called by the President with the approval of the Executive Committee.

2. In the event of an emergency, the Executive Committee shall have the power to cancel a regular or annual meeting, or to change the place of an annual meeting; and in the event of such cancellation the Executive Committee shall have the power to schedule the next regular meeting.

3. A quorum at any meeting for the transaction of official business shall consist of at least twenty-five active members in good standing.

4. Decisions at meetings, including election of members, shall be by a majority of those present at any meeting; *except that* for election of officers and members of committees, and for a motion for amendment of By-laws adopted pursuant to Article V, a two-thirds majority shall be required; and *excepted further,* a unanimous vote shall be required for the election of honorary members.

ARTICLE V

Authorization for the Adoption of By-laws

1. The Society is authorized to adopt and to amend subsequently as may be required, in accordance with the provisions of paragraph 4 of

Article IV, such By-laws as may be necessary for the conduct of the business of the Society.

2. By-laws adopted pursuant to the provisions of this Article must include, but shall not be limited to, the following:

(a) Set forth the amount of annual dues and special fees or assessments for the various classes of membership of the Society, and deal with other matters pertaining to the finances of the Society.

(b) Prescribe the duties of officers of the Society.

(c) Provide for the establishment of and specify the terms of reference or duties of such standing committees, other than the Executive Committee established in accordance with paragraph 4 of Article III, and such sessional committees as may be necessary for the conduct of the business of the Society and the furtherance of its purposes and objectives. For the purposes of this subparagraph, (1) a standing committee is defined as one which is established permanently in the By-laws as a part of the basic organization of the Society; and (2) a sessional committee is defined as one constituted for the purpose of undertaking specific tasks at or in preparation for a regular or special meeting of the Society and is discharged upon submission of its report or completion of its business.

(d) Notwithstanding the provisions of subparagraph (c) of this paragraph, the President with the consent of the Executive Committee may appoint, or the Society, by adoption of an appropriate resolution, may authorize the President to appoint *ad hoc* committees to undertake special assignments; any such authorization or appointments shall not require amendment of the By-laws, and such committees shall automatically be abolished on completion of their assignments or on the date of the next regular meeting, whichever occurs first.

(e) Provide authorization for such official publications of the Society as may be necessary in the furtherance of its purposes and objectives.

(f) Provide for the establishment and maintenance of any regional divisions of the Society established pursuant to the provisions of Article VI.

ARTICLE VI

Regional Divisions

1. A regional division of the Society may be established by the favorable action of the Society, pursuant to paragraph 4 of Article IV, upon a petition presented to it at any regular meeting by not less than twenty-five members of the Society in good standing resident in a particular geographic region.

2. Such regional division or divisions shall be organized in accordance with pertinent provisions of the By-laws adopted pursuant to Article V.

3. Each such regional division may adopt and amend from time to time its own By-laws, which shall conform to the provisions of this Constitution and By-laws of the Society adopted pursuant to Article V. The By-laws of regional divisions, after adoption and each amendment, shall be reviewed by the Executive Committee of the Society to insure conformance with the Constitution and By-laws of the Society. No By-laws of regional divisions or amendments thereof shall be considered effective until

such review by the Executive Committee of the Society has been completed and the chairman of the regional division has been notified in writing by the Secretary-Treasurer of the Society that such by-laws or amendments thereof are in conformity with the Constitution and By-laws of the Society.

4. Each regional division shall elect its officers, which shall consist of a chairman, vice-chairman and secretary. The chairman of any regional division shall be a member of the Executive Committee of the Society, and in his absence or inability to attend meetings of the Executive Committee the vice-chairman of that regional division may act in his stead. The secretary of any regional division of the Society shall serve as an assistant to the Secretary-Treasurer of the Society and shall carry out his duties in accordance with such procedures as may be determined from time to time by the Secretary-Treasurer of the Society.

5. All members of the Society who reside within a designated region in which a regional division of the Society may be established shall, upon election to membership and payment of dues prescribed in the By-laws, be considered a member both of such regional division and of the Society as a whole. Qualifications for membership in regional divisions shall conform to qualifications for membership in the Society. Regional divisions may elect active and life members only. The other classes of membership set forth in Article IV shall be elected only by the Society.

6. The regional divisions may, with the approval of the Executive Committee of the Society, levy such special fees, in addition to the dues of regular members of the Society, as may be necessary to meet any expenses of the regional divisions which are not properly chargeable to the regular funds of the Society. All regular Society dues shall be paid only to the Secretary-Treasurer of the Society. Any special fees collected by the regional division shall be disbursed by the secretary of the regional division in accordance with the By-laws of such regional division and the authorization of its officers and members.

7. The Executive Committee may allot to any regional division, from time to time, such sums from the treasury of the Society as may be necessary to further through the regional division the purposes and objectives of the Society. Such allotted funds shall be disbursed by the secretary of the regional division in accordance with its By-laws and the decisions of its officers and membership.

ARTICLE VII

Amendment of Constitution

1. This Constitution, after adoption in accordance with the provisions of the existing Constitution and By-laws, shall supersede such previously adopted Constitution.

2. This Constitution may be amended upon unanimous recommendation of the Executive Committee which shall be circulated in writing to the membership at least 30 days prior to any regular meeting at which a vote is to be taken, and upon approval by a two-thirds majority of the members present at such regular meeting, provided a quorum is present.

3. A petition for amendment of this Constitution signed by not less than 50 members in good standing, irrespective of any action relative thereto taken by the Executive Committee in pursuance of paragraph 2 of this Article, shall be circulated to the membership by the Secretary-Treasurer at least 30 days prior to a regular meeting, and such amendment shall become effective upon approval by a two-thirds majority of the members present at such regular meeting, provided a quorum is present.

BY-LAWS OF THE AMERICAN FISHERIES SOCIETY

Section 1.—Duties of the President

The President is responsible for the business and organization of the Society, shall make such appointments as are authorized in the By-laws, and shall exercise such other functions and responsibilities as may be determined from time to time by action of the Society or the Executive Committee. He shall preside at all meetings of the Society, and at all meetings of the Executive Committee, of which he is chairman.

Section 2.—Duties of the Vice-Presidents

The First Vice-President shall assume the duties of the President during his absence or in case of his inability to act. The Second Vice-President shall assume the duties of the President during the absence of the President or the First Vice-President or in case of their inability to act. The First Vice-President is chairman of the Membership Committee provided for in Section 16, and in case of his absence or inability to act such chairmanship shall be assumed by the Second Vice-President. Upon designation by the President, the First Vice-President or the Second Vice-President shall preside at any necessary simultaneous sectional sessions at regular meetings.

Section 3.—Duties of the Secretary-Treasurer

The Secretary-Treasurer, in his capacity as Secretary, shall be responsible for maintaining the official records of the Society, shall conduct its official correspondence, promote its membership, and shall make arrangements for regular and special meetings of the Society, and for meetings of the Executive Committee. He shall serve as parliamentary advisor to the President and chairman of committees to insure that the business of the Society is conducted in accordance with the provisions of the Constitution and By-laws.

The Secretary-Treasurer, in his capacity as Treasurer, shall receive and collect all dues, fees, accounts receivable, and other income of the Society, shall have the custody of its funds, and shall pay all accounts payable and other claims which have been duly authorized and approved. He shall furnish a bond in the sum of $7,500, on surety, to be approved by the Executive Committee, the premium for such bond to be paid by the Society. The Secretary-Treasurer shall present an annual report to the Society.

Section 4.—Duties of the Librarian

The Librarian shall have the custody of the library of the Society, including its archives and printed publications, and shall have charge of the sale of extra copies of its publications. He shall transmit promptly to the Secretary-Treasurer monies received from such sales.

Section 5.—Expenses of Officers

No elected officer or committee member of the Society shall receive any salary or other compensation for his services. Clerical and other necessary expenses of elected officers and committee members may be defrayed by the Society provided that it has, through action at a regular meeting, or by vote of the Executive Committee in the event of an emergency during the interval between regular meetings, authorized such disbursements in advance.

Section 6.—Official Publications

The minutes and proceedings of all regular and special meetings of the Society and of any regional division established pursuant to Article VI of the Constitution, together with reports of officers and committees at such meetings, technical papers furnished by members and selected by the Editorial Board for publication, and the official membership list of the Society shall be published in an annual volume which shall be numbered in series with the preceding volumes and shall be entitled: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY. Each active member, life member, library member, sustaining member, and official member shall receive one copy of the annual volume of the TRANSACTIONS. Honorary members shall be sent a copy of each volume of the TRANSACTIONS only on receipt of a written request therefor. Special publications may be written with the direction or with the approval of the Society or the Executive Committee at any official session.

Section 7.—Presentation and Publications of Manuscripts

Only members in good standing may present papers, either by reading or by title, at annual meetings of the Society or submit them for publication by the Society; *except* that outstanding non-members invited by the President of the Society, or Secretary-Treasurer with the advice of the President, who present papers at any meeting shall be exempt from this

requirement. No member may have listed on the program of any meeting of the Society or any regional division thereof, or present, or have published in any one volume of the TRANSACTIONS, more than two papers; and for purposes of this section joint authorship shall be considered in the same status as sole authorships.

Section 8.—Dues of Members

The dues of the various classes of members, payable to the Secretary-Treasurer of the Society, shall be as follows:

(a) Active member, $4.50 per annum.

(b) Life member, $75; payable, if desired, in two consecutive annual installments of $37.50 each.

(c) Library member, $4 per annum.

(d) Sustaining member, $10 per annum.

(e) Official member, $40 per annum.

(f) Patron, a single contribution of $250 or more.

(g) Honorary member, no dues.

All dues, fees, or other monies due the Society shall be paid in currency of the United States of America, or the equivalent in foreign currency at current rates of exchange in the United States of America.

Section 9.—Loss of Membership

Any member who fails to pay his dues for a period of more than one year shall be given written notice by the Secretary-Treasurer that his name will be removed from the membership list unless back dues are paid in full within 60 days from the date of such notice. Any member who has forfeited his membership may not be reelected as a member for a period of one year from date of forfeiture of his membership unless he has paid all back dues and has paid dues for one additional year in advance.

Section 10.—Committee on International Relations

The Committee on International Relations is a standing committee responsible for keeping the Society informed as to the work of foreign technical agencies, international organizations, meetings, conferences, negotiations, exchange of persons and information, and related international matters of interest to the Society, and shall recommend such action or participation by the Society as may be appropriate in the furtherance of the Society's purposes and objectives. It shall consider problems of legislation and implementation of international agreements relating to the interests, purposes and objectives of the Society. The Committee shall consist of seven members in good standing, who shall be named by the nominating committee and elected by the Society. The Committee shall report to the Society annually concerning its work.

Section 11.—Committee on National-State Relations

The Committee on National-State Relations is a standing committee which shall act as a coordinating and advisory board for the consideration of interstate and National-State fishery problems and programs in the United States of America. It shall also consider problems of administration of fishery resources, and Federal and State legislation and the implementation thereof in the fields of fishery conservation and management. The Committee shall consist of five members in good standing, at least one and no more than two of which shall be an officer or officers of the United States Government, who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, which report shall include such recommendations for action by the Society as are considered appropriate.

Section 12.—Editorial Board

The Editorial Board is that standing committee responsible for the editing and publication of the TRANSACTIONS and of any special publications of the Society. This Board shall consist of five members in good standing of proved technical and editorial abilities each of whom shall serve for a term of five years. Each President, immediately upon his election, shall appoint one new member of the Board and shall designate the chairman for the ensuing year. The chairman of the Editorial Board shall be known as the "Editor" and the other members shall be known as "Associate Editors." The Editor shall assign duties to the Associate Editors, and may solicit assistance, from time to time, for temporary periods from other members of the Society. The Board is authorized to establish and issue such standards and instructions to the membership as may facilitate its work. The Board shall report to the Society annually concerning its work.

Section 13.—Committee on Hydrobiology and Fish Culture

The Committee on Hydrobiology and Fish Culture is a standing committee which shall maintain a continuous survey and appraisal of research and applied work in the fields of aquatic biology, physiology, limnology, and oceanography as related to fishery science, fish culture, and fishery management. It shall develop and encourage the standardization and improvement of techniques, procedures, nomenclature, and measurements; and shall consider problems of pollution control. The Committee shall be composed of seven members in good standing who are recognized specialists in various phases of fishery science and practice, and who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, placing emphasis on developments during the past year.

Section 14.—Committee on Commercial Fisheries

The Committee on Commercial Fisheries is a standing committee responsible for promoting and improving fishery techniques and the utilization of fishery resources for food and by-products, for the development and recommendation of standards of quality and sanitation, for the development and recommendation of standardized procedures for the collection and analysis of fishery statistics, and for related activities. The Committee shall be composed of seven members in good standing who are recognized specialists or authorities in fishery economics, technology, or the fishery industries, and who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, placing emphasis on developments during the past year.

Section 15.—Committee on Names of Fishes

The Committee on Names of Fishes is a standing committee responsible for the establishment and maintenance of a check list of common and scientific names of fishes, with the objective of achieving uniformity and avoiding confusion in nomenclature. The Librarian shall be custodian of the master check list. The Committee, in the furtherance of its duties, shall coordinate its activities with those of other societies and organizations throughout the world. The Committee shall be composed of seven members named by the nominating committee and elected by the membership, such members to be outstanding specialists in the fields of systematic ichthyology and fishery biology. The Committee shall report to the Society annually concerning its work.

Section 16.—Membership Committee

The Membership Committee is a standing committee responsible for maintaining and increasing the membership of the Society. The Committee shall take such measures as it deems appropriate and effective to stimulate interest in the Society and to further its purposes and objectives by interesting qualified persons in membership. The committee shall consist of the First Vice-President, who shall be chairman, and nine other members in good standing who shall be appointed by the President within 30 days after his election. The Secretary-Treasurer shall be an *ex-officio* member. The Committee shall report to the Society annually concerning its work.

Section 17.—Program Committee

The Program Committee is a standing committee responsible for arrangement of the program at the regular meetings, consisting of technical sessions for the reading and discussion of original papers, symposia on important topics, and exhibits of interest to the Society. It is the duty of the Committee to insure that the programs at the regular meetings are of high quality and achieve balance among the various fields

of interest and activity of the Society. The Committee may recommend to the President the issuance of invitations to outstanding non-members to present papers or addresses. The Committee shall consist of five members in good standing appointed by the President within 30 days after his election, who shall serve until the close of the next annual meeting.

Section 18.— Sessional Committees

The President is authorized to appoint, from the members of the Society in good standing, prior to, or at the beginning of each regular meeting, such sessional committees as may be necessary for the conduct of the business of the Society and other authorized activities in conjunction therewith; including the following:

(a) Nominating Committee of five, which shall name a list of officers and members of Committees that are subject to election by the Society, which shall be presented to the members for action at a regular meeting. It is the duty of the Committee to insure that all persons named shall conform to the qualifications for the various offices and committee memberships set forth in the Constitution and By-laws. The right of any member to nominate a candidate for any office or committee membership from the floor during a regular meeting, or to second such nomination, is expressly reserved.

(b) Resolutions Committee of five, which shall draft and recommend to the Society for consideration and vote at a regular meeting such resolutions, including amendments of the By-laws, as may be considered prudent and necessary for the furtherance of the purposes and objectives of the Society and for the conduct of its business.

(c) Auditing Committee of three, which shall examine the accounts of the treasurer and report its findings to the Society, and shall consider the annual budget of the Society prepared by the Secretary-Treasurer with the advice of the Executive Committee, and make recommendations concerning it for the action of the membership.

(d) Time and Place Committee of five, which shall consider and recommend to the membership for action, the time and place for the next regular meeting.

(e) Publicity Committee of three members, which shall draft, approve, and disseminate appropriate press notices and reports concerning the meetings of the Society and the proceedings thereat as may be appropriate and in furtherance of the purposes and objectives of the Society.

Section 19.—Order of Business The order of business at regular meetings of the Society shall include, but shall not necessarily be limited to, the following:

1. Call to order by the President.
2. Address of the President on a timely subject of his choice.
3. Roll call of members (or determination that a quorum is present).
4. Action on nominations for membership.
5. Introduction of noteworthy guests and visitors.
6. Appointment of sessional committees by the President:
   a. Nominating Committee of five.
   b. Resolutions Committee of five.
   c. Auditing Committee of three.
   d. Time and Place Committee of five.
   e. Publicity Committee of three.
7. Report of the Secretary-Treasurer.
8. Report of the Librarian.
9. Report of the chairmen of regional divisions.
10. Reports of Standing Committees.
11. Reports of *ad hoc* committees.
12. Program of papers, symposia, and discussions.
13. Report of the Time and Place Committee.
14. Report of the Auditing Committee.
15. Report of the Resolutions Committee.
16. Report of the Nominating Committee.
17. Election of officers and members of such standing committees as are subject to election by the membership.
18. Installation of newly-elected officers.
19. Other business.
20. Adjournment.

Section 20.—Northeastern Division (a) In accordance with the provisions of Article VI of the Constitution there is established a Northeastern Division of the American Fisheries Society which consists of members in good standing from the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia, and the District of

Columbia in the United States of America, and the Provinces of New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island, and Quebec of the Dominion of Canada.

(b) The Chairman of the Northeastern Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the Northeastern Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

Section 21.— Southern Division

(a) In accordance with the provisions of Article VI of the Constitution there is established a Southern Division of the American Fisheries Society which consists of members in good standing from the states of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and members residing in Cuba, Puerto Rico, the Virgin Islands, and other West Indian Islands.

(b) The Chairman of the Southern Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the Southern Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

Section 22.— Western Division

(a) In accordance with the provisions of Article VI of the Constitution, there is hereby established a Western Division of the American Fisheries Society, which consists of members in good standing from the states of Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming and the Territories of Alaska and Hawaii of the United States of America; and from the Provinces of Alberta, British Columbia, and Saskatchewan of the Dominion of Canada.

(b) The Chairman of the Western Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the Western Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

INSTRUCTIONS FOR PREPARING MANUSCRIPTS FOR THE TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

(REVISED 1953)

Please check each item below before the final typing of your manuscript and help your Society reduce the costs of publication, save your Editorial Board (which works gratis) much needless work, time, and expense, and avoid delay in the publication of the *Transactions*.

The following instructions were not drawn up arbitrarily but were condensed from the regulations contained in the best style manuals. Certain instructions may appear unnecessary, but they are nevertheless essential for the proper handling of materials by the printer and the editor.

I. MECHANICAL DETAILS

1. **Manuscript must be typewritten double-spaced,** including titles, headings, legends for tables and illustrations, and literature citations. Write manuscript only in simple upper and lower case. *Do not use all capital letters for any purpose and underscore only where italics are intended.*

2. **Carbon copies or originals made with a worn-out ribbon will not be accepted.** Do not use thin paper; heavy bond is preferred.

3. **Margins** at top, bottom, and both sides must be no less than 1¼ inches to allow space for the insertion of directions to the printer and necessary corrections.

4. **Pages must be numbered in consecutive order,** including tables and pages carrying legends to figures. Tables and legends of figures must be inserted near their place of reference in the text.

5. **Illustrations.** Make a separate page of each legend of figures and limit the number of both to those absolutely necessary to clarify or supplement text. *Tables and cuts cost money!* Only sharp, glossy photos can be used. Photostats will not be accepted. All drawings, charts, and diagrams should be prepared in waterproof India ink on Bristol Board, other perfectly smooth white paper or cardboard, or tracing cloth. Graph paper must not be used. No erasures should be made. Shading should be limited to a minimum and when used the shading lines should be kept open. The curves of graphs should be drawn much bolder than any guide lines or ruling. Lettering should be bold and sufficiently large and spaced apart so that the letters or numbers will not be less than 1 millimeter high or come in contact when reduced. Drawings should be made at least twice the size required for reproduction, and when large should be of proper proportion so that they will not exceed 4¼ by 6½ inches (inclusive of legends) when reduced. *All explanatory matter other than the units along each axis of a graph or diagram and those designations needed for clarity should be placed in the legend.* The legend, which should be typewritten on a separate sheet, will be set in type below the figure.

Make proper reference in text to all plates, maps, and charts, and designate all of these, except tables, as figures, numbering them in consecutive order with Arabic, not Roman, numerals.

6. **Footnotes** in text should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do not break a line of text to insert footnote. Separate the footnote from the text by two horizontal lines, one above and one below the note. In each new table footnotes should begin with 1.

7. **The title** of the manuscript, together with the author's name, position or department, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least *triple space between lines* to permit the insertion of instructions to the printer.

REPORT ON THE DISEASES OF BROOK TROUT

John Edward Doe

Department of Conservation, Lansing, Michigan

8. **Underscore** (italics) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: Esocidae; *Esox lucius. Do not underscore any words unless italics are intended.*

9. **Inspect papers** in the last volume of the *Transactions* if you have questions concerning the arrangement of materials.

II. STYLE

10. **Bibliographic references** in text should give name of author and year of publication in parentheses, thus (Doe, 1932). Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any reference not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below to be placed at end of paper:

Literature Cited

Doe, John C., J. W. Brown, and H. W. Green

1939. Report on the diseases of brook trout. Trans. Am. Fish. Soc., Vol. 68 (1938), pp. 450–461.

List only bona fide publications under Literature Cited. Do not list personal communications, typewritten reports, or processed materials given only limited distribution.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the *Transactions* have been found to be incomplete and inaccurate. Help us correct this situation.

11. **Tables.** Every table except leader work must have a heading and must be typewritten on a separate page. In preparing tables please make certain that they are not too large to appear on a single printed page and that the arrangement conforms with the format of the *Transactions. Improperly prepared tables lead to the return of many manuscripts.* Number tables consecutively with Arabic numerals (1, 2, 3, etc.). Spell all words in tables, including such words as "millimeters," "ounces," and "average" (except months *with date,* in body of table), and capitalize, as a rule, the first word only in headings in the first column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

Item	Number of fish	Percentage of total	Average length (millimeters)	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	6.5	April-September	$0.25

12. **Capitals.** Capitalize words when used as part of a proper name or of an identifying number or letter, or when referring to a particular State, Government, and to organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, or the State, the Province, the Republic, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Hoover Dam, Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but use lower case for a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 8 (referring to illustrations).

Use lower case for scientific and common names of species. Capitalize scientific names of higher categories.

13. **Abbreviations.**

(a) Abbreviate the following:

Clock time, if connected with figures—2:30 a.m.

Temperatures, F. (Fahrenheit).

Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.

Number, if preceding figures—No. 125; otherwise spell out.

United States, if preceding name of a department or a bureau of a vessel, etc.—U. S. Department of the Interior, U. S. S. *Indiana.*

Months, in body of tables and footnotes to same when followed by day of month—Apr. 5–Sept. 2 (but April–September).

(b) Do not abbreviate the following:

States, cities, etc.

Months, in text or in headings of tables—April 5–September 2.

Measures and weight, except p.p.m., 6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage, 12 percent, a percentage of 25.5.

14. **Numerals.** Spell out *isolated* numbers less than 10, but use figures in a group of enumerations when any one number of that group is 10 or greater. Do not spell out numbers of two or more digits and always use a comma in a number of four or more digits. Treat alike all numbers in a series of connected groups. For example: There were nine trout. There were 9 trout, 120 bass, and 50 pike.

Use figures for enumerations of quantities and measurements, such as dimension, weight, area, volume, distance, clock time, time, money, percentage, degrees, proportion or ratios, ages, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone but use numeral if part of a hyphenated expression: one-half inch; ½-inch mesh). Examples: $3.00 per 20 pounds; 5 feet 6 inches; 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish died in 1 hour and 20 minutes; 25.5 percent; 75° F.; 1:10,000; trout 2 years 6 months old; 2-year-old trout; June 29, 1936; January 1938; the 20th day of March; 1937-1938; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50-50, not "fifty-fifty."

Do not use two figures when two numbers appear together, unless the first enumeration exceeds 100: ten 12-room houses; twenty 6-inch bluegills; 120 6-inch bluegills.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five trout," but write "Two hundred fifty bass and 325 trout were shipped."

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 2¾ billions.

15. **Use of hyphen.** Many compound words when used as nouns are not hyphenated but require the hyphen when used as adjectives. For example note the following sentences: "This species is adapted to *"cold water."* "Ciscoes are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

III. SUBJECT MATTER

16. **Condense your paper** to the limit and omit all needless verbiage to reduce cost of printing. The manuscript should be simple, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. Have your associates read and criticize your paper before the final typing. **Papers which are too poorly written will be rejected.**

17. **Be definite in reference to species.** The full common name and the scientific name must be given for each species mentioned. Scientific names may be omitted from the title, if desirable, but must be given at first reference to the species in the text. Once given, scientific names need not be repeated. Follow the Society's official list of names. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth bass," "brook trout," "rainbow trout," etc.

18. **Things to avoid.** Words that do not appear in the dictionary in the sense employed should be avoided. The words "case," "instance," "show," "found," "gave," and "present" are greatly overworked in manuscripts.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives*. Please check your manuscript for this exceedingly common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: *"This* was true in every *case." "The mortality* was *high* in every *pond."*

Avoid the use of a long series of nouns and adjectives as modifiers.

Avoid the use of such meaningless section headings as "Data" and "Discussion."

19. **Abstract of paper.** Give a brief abstract at the beginning of your paper. Do not include a "Summary" at the end of your paper; if "Conclusions" are given make them brief and not a duplication of materials in the abstract.

Prepared by the Editorial Board
February 1937 (revised 1953)

AMERICAN FISHERIES SOCIETY

LIST OF MEMBERS

Compiled June 15, 1953

HONORARY MEMBERS

The President of the United States
The President of Mexico
The Secretary of the Interior of the United States
The Governors of the Several States
The Governor-General of Canada
The Lieutenant-Governor of the Several Canadian Provinces
The Dominion Minister in Charge of Game and Fisheries
'08 Anderson, August J., Box 704, Marquette, Mich.
'00 Bower, Ward T., Suwannee Hotel, St. Petersburg 1, Fla.
'27 Gordon, Seth, Div. of Fish & Game, 926 J St., Sacramento 14, Calif.
'04 Hayford, Charles O., State Fish Hatchery, Hackettstown, N. J.
'18 Moore, Emmeline, Slingerlands, N. Y.
'19 Rodd, J. A., Dept. of Fisheries, Ottawa, Ont.
'28 Van Oosten, John, University Museum, Ann Arbor, Mich.
'00 Wood, Colburn C., Box 355, Plymouth, Mass.

PATRONS

'15 Fuller, W. P. & Co., 301 Mission St., San Francisco, Calif.
'50 Perk Foods Co., Fish Feed Dept., 500 N. Dearborn St., Chicago 10, Ill.

ACTIVE MEMBERS

[Life Members indicated by asterisk; Honorary Life Members by boldface]

'50 Aberg, Wm. J. P., 3401 Lake Mendota Dr., Shorewood Hills, Madison, Wis.
'51 Adair, A. R., 913 W. Munising Ave., Munising, Mich.
*'48 Adams, Arthur K., University Museums Annex, Ann Arbor, Mich.
'51 Adams, Harry E., U.S.N., R.T.C., Bainbridge, Md.
*'50 Adams, Robert T., Box 156, Whitehall, Mont.
'52 Aguayo, Carlos G., Museo Poey, Universidad de la Habana, Cuba
'50 Ahmad, Nazir, Directorate of Fisheries, Camilla, East Bengal, Pakistan
'30 Ainsworth, A. L., Tuxedo Fisheries, Tuxedo Park, N. Y.
'50 Aldana, Adolfo M., San Jacinto, Pangasinan, Philippines
'50 Alderdice, D. F., 173 Tower St. W., Saint John, N. B.
'32 Aldrich, A. D., 1312 NE 40th St., Oklahoma City, Okla.
'35 Alexander, George J., Parliament Bldg., Victoria, B. C.
'37 Allen, Edward W., Northern Life Tower, Seattle, Wash.
'52 Allen, George H., Route 1, Box 1313A, Grants Pass, Ore.
'50 Allen, J. Frances, Dept. of Zool., Univ. of Maryland, College Park, Md.
'49 Allen, K. Radway, Box 202, Wellington, New Zealand
'52 Allen, Walter M., Supt. State Fisheries, Helena, Mont.
'30 Allen, William R., Dept. of Zool., Univ. of Kentucky, Lexington, Ky.
'49 Allin, Roger W., Route 2, Carterville, Ill.

'43 Allison, Leonard N., State Fish Hatchery, Grayling, Mich.
'49 Allum, Marvin O., Box 255, Woonsocket, S. D.
'52 Alperin, Irwin M., 2845 Ocean Ave., Brooklyn 35, N. Y.
'50 Alvord, William, Box 1253, Havre, Mont.
'51 Ancieta, Luis F., Direccion de Pesqueria y Caza, Ministerio de Agricultura, Lima, Peru
'49 Andersen, Edward H., Conservation Headquarters, Baldwin, Mich.
'45 Anderson, Andrew W., U. S. Fish & Wildlife Service, Washington 25, D. C.
'08 **Anderson, August J.**, Box 704, Marquette, Mich.
'41 Anderson, Bertil G., West Virginia Univ., Morgantown, W. Va.
'53 Anderson, G. M., Box 40, Jemez Springs, N. M.
'49 Anderson, Ima F., Yazoo City, Miss.
'52 Anderson, James W., Prov. Fish Hatchery, Normandale, Ont.
'50 Anderson, Leland R., Conservation Headquarters, Newberry, Mich.
'52 Anderson, Richard O., 1728 S. Maple Rd., Ann Arbor, Mich.
'43 Anderson, William W., P. O. Box 283, Brunswick, Ga.
'49 Andrews, Jay D., Virginia Fisheries Lab., Yorktown, Va.
'49 Andrews, Thomas J., Fernald Hall, Univ. of Massachusetts, Amherst, Mass.
'53 Andriano, Donald, 1024 Bridger St., Pocatello, Idaho
'25 Annin, Harry K., Spring St., Caledonia, N. Y.
'14 Annin, Howard, Chilmark Park, Ossining, N. Y.
'47 Anthony, James D., 2655 Bellewood Ave., East Ann Arbor, Mich.
'53 Apelgren, Bert, Wisconsin Conservation Dept., Black River Falls, Wis.
'49 Appelget, John G., U. S. Fish & Wildlife Service, Blake Bldg., Boston 11, Mass.
'50 Apple, W. M., 47 Sherrill Hts., Little Rock, Ark.
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